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Protein Metabolism Studies on Reduced Caloric and Water Intake

SUMMARY

During August and September, 1945, metabolic studies were made on ten healthy volunteer Conscientious Objectors receiving 800 cc. water and 200 Gm. food (850 calories) daily for ten consecutive days. One group of five men ate a protein-free diet composed (by weight) of 90% carbohydrate and 10% fat; the other, a diet consisting of 80% carbohydrate, 10% fat, and 10% protein derived from malted milk.

In October, these studies were duplicated with the same subjects, with the exception that dried egg albumin was used instead of the malted milk protein. The daily ration was again 200 Gm., but a difference in moisture content resulted in a caloric value of 800.

By comparison with the protein-free regime serving as control, the diet containing 10% malted milk protein produced a slightly greater weight loss, significantly higher urinary volume, total urinary solutes, and total urinary nitrogen. There was also a definite increase in the daily output of urinary sodium and potassium, and some decrease in the urinary ammonia nitrogen.

In contrast with the malted milk protein, the dried egg albumin ration produced very little increase in total weight loss and in urinary volume. Although the total solutes and nitrogen of the urine exceeded somewhat those found with the accompanying protein-free regime, these differences were much smaller

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than with the malted milk protein. Positive nitrogen balance was not attained, but of the 2.9 Gm. nitrogen fed daily, 1.4 Gm. was retained. Averaged group data are detailed in the accompanying tables and figures.

It appears, then, that dried egg albumin is superior to malted milk protein in the 800-850 calorie range in the presence of limited water intake.

Further dietary studies are now in progress, and additional reports on completed work are now in preparation.

INTRODUCTION

The object of these experiments is the study of the basic human physiology under conditions of specific limitation of food and water. Originally the work was directed primarily towards Life Raft Rations, but more recently the outlook has been broadened to include general survival rations.

Emphasis is being placed on the variations in protein, fat, and carbohydrate content, and in caloric intake, which will afford maximal chances not only for survival, but also for maintenance of fitness in normal human beings.

Special attention is being paid to the advisability of including protein in the rations. If found feasible, the inclusion of protein may be of great value to men suffering from injury, blood loss, or shock. Protein could also make rations more palatable.

A major problem in this respect is the question of retention of protein by the body and maintenance of nitrogen equilibrium. Since the nitrogenous end-products of protein metabolism classically require additional urine water for excretion, it would be uneconomical, with a limited water intake, to feed a protein which would not be retained. It would be distinctly advantageous, then, if a type or form of protein were found which, perhaps under certain conditions, would promote a retention of nitrogen by the tissues. Preliminary experimentation with animals has indicated that such an objective may not be unattainable.

The investigations here reported (Experimental Diets #9, 10, 11, and 12) are a continuation of studies begun in January, 1945. The latter included Experimental Diets #1-8, inclusive, of our numerical series, and were reported to the Committee on Food Research in June, 1945. Since these data were never mimeographed for general distribution by the Committee, and since they comprise an integral part of the studies to be reported now and in the future, we include the following summation of our earlier work:

SUMMARY OF FINDINGS WITH EXPERIMENTAL DIETS # 1 - 8, INCLUSIVE *

1. Ten normal adult males were divided into groups and subjected to a series of five experimental dietary regimens for five days, and to three experimental regimens for ten days.

2. The daily diet per man weighed 100 Gm., and supplied from 400 to 525 calories.

3. The intake of water was standardized at 800 cc. per man per day. During the ten-day experimental period, 1 Gm. of NaCl was added to each man's daily ration of water.

4. Despite weakness, dehydration, and loss of weight, all subjects were in relatively good physical and mental condition at the end of both the five and ten day testing periods, regardless of which of the eight experimental diets had been consumed.

5. Severe muscular pains occurred during the first testing period of five days. These muscular pains did not appear during the ten day experiment, when 1 Gm. of NaCl was added to the daily ration of water. There were also less nausea, headache, insomnia, and general malaise during these longer experiments.

6. Constipation occurred as a result of the general limitation of food and water; this was independent of the composition of the individual diet. The diet containing 25% fat caused abdominal distress, including gaseous distension, cramps, flatulence, and nausea.

7. As measured by psychological and

* See Table #4A page 3A

TABLE #4A

PERCENTAGE COMPOSITION OF EXPERIMENTAL DIETS # 1 - 8, INCLUSIVE

DIET	CHO	PROT.	FAT
1	100	--	--
2	90	10	--
3	80	20	--
4	65	10	25
5	100	--	--
6	86	4	10
7	90	--	10
8	78	12	10

Dehydrated (uncoagulated) egg white was the source of protein in Diets #2, 3, 4, and 8; malted milk powder was used in Diet #6.

performance tests, capacity for muscular work was decreased in all subjects, but neural functions were not significantly disturbed.

Psychological tests were of limited usefulness in differentiating between the small groups of subjects because of large individual variations in response.

8. During "deprivation", fatigue and thirst increased rapidly, abdominal discomfort and dizziness, slowly. Hunger increased rapidly for three days, after which it was progressively less intense.

9. Loss of weight occurred in all subjects; the greatest rate of decrease was noted during the first two days. There was less loss of weight during the first five days of the ten day experiment than during the initial five day experiment.

Losses in water (urine) paralleled changes in weight.

10. Urinary volume decreased in all cases, but never to critical levels.

11. The addition of protein or fat to the diet lessened the decrease in urinary volume.

12. The addition of even the smallest amount of protein (4%) to the diet produced an increase in the total solutes of the urine.

13. Dehydration caused the appearance of albumen, casts, leucocytes, and erythrocytes in the urine of certain subjects who may have had some previously unrecognized diminution of renal reserve.

14. All experimental groups exhibited a general increase in hematocrit, erythrocyte, and hemoglobin values during the first three to four of the experimental days, after which they returned to and remained normal.

15. Tests of hepatic function indicated no impairment of the liver through "deprivation."

16. Under the experimental conditions used, there was no alteration in the pH, the specific gravity, or in the creatinine of the urine. No acetone bodies appeared in the urine at any ttime.

17. The white blood count and the rate of sedimentation of the erythrocytes were unaffected by the respective experimental regimens..

18. Changes in the basal metabolic rate, (capillary permeability, fluorescein excretion, and ascorbic acid levels (tissue and plasma) showed no changes which were traceable to the experimental conditions.

19. In one subject, a pre-existing bigeminal rhythm disappeared during salt deprivation.

20. The total non-protein nitrogen in the blood rose as "deprivation" progressed, the highest levels being reached by the fifth to seventh days. No clinical symptoms whatsoever were present which could be attributed to accumulation of nitrogenous substances in the blood.

21. The urinary nitrogen decreased sharply during the experimental periods. The greatest drop occurred in the first two days. The addition of protein to the diet lessened this decrease. The inclusion of fat counteracted this effect of protein somewhat. Salt may have had a similar effect.

22. The excretion of urea nitrogen paralleled that of total nitrogen.

23. There was a phasic variation in the excretion of creatine in the urine, with increases until the fourth and fifth days, followed by decreases. Secondary elevations occurred in the subjects on Diets 7 and 8. The addition of

small amounts of protein to the diet produced some decrease in creatinuria. Addition of salt delayed the rise in creatinuria.

24. Blood and urinary sodium values dropped during both experimental periods, but the fall was much slower and less marked when 1 Gm. of NaCl was included in the rations.

25. Chloride levels in the blood decreased during the five-day "deprivation", and were still subnormal on the sixth recovery day. When NaCl was provided, the sodium concentration had returned to normal between the third and seventh experimental days.

The excretion of chlorides in the urine dropped sharply in the first five days of both testing periods. The urinary chloride levels remained low throughout the latter half of the ten-day experiment. The decrease in urinary chlorides was somewhat less in the subjects receiving protein than in those who were not.

26. Potassium concentration in the blood rose in all subjects, but the rise was less when they were receiving NaCl than when they were not.

27. Urinary potassium values dropped rapidly in the first two days of the five-day testing period, and thereafter rose again. In the ten-day period, when NaCl was added, the urinary potassium did not reach its lowest level until the seventh experimental day, after which it rose gradually.

In these first eight experimental diets, the daily ration was set at 100 Gm. to conform with the level present in the standard Army Air Forces Life Raft Ration. The 800 cc. figure for the daily water allotment was determined as the average amount expected to be available to a Life Raft passenger from the combined use of sun still, desalination kit, and rain water.

The 200 Gm. food level in Diets #9, 10, 11, and 12 herein reported was originally chosen as approaching 50 per cent of minimal caloric requirement. (The influence of caloric levels will be discussed in greater detail in a forthcoming report). The use of such higher caloric intake was encouraged by the animal work of Swanson and of Allison (1), who reported that they promoted increased nitrogen retention. It was also hoped that the Air Force would provide the small additional space required if such rations proved definitely superior.

METHODS AND MATERIALS

The general plan of this study has included three consecutive periods in each experiment:

1. A seven-day standardization and control period
2. A ten-day testing ("deprivation") period
3. A five-day recovery period

I Subjects

Ten volunteer Conscientious Objectors were used as subjects. They ranged in age from 20 to 37, and in weight from 137 to 178 pounds.

These men were considered to be in good health. All had passed Army Induction physical examinations before assignment to Civilian Public Service Camps. Preliminary to acceptance as a test subject, the physical status of each man was thoroughly checked by a careful history, physical examination, electrocardiogram, chest roentgenogram, blood count, uninalysis, erythrocyte sedimentation rate, blood sugar, urea nitrogen, and Wasserman test.

II Environmental Conditions

The subjects were confined, during control as well as experimental periods, to Ward K of the Research Unit as regular patients. They were allowed to be ambulatory on the premises, but at no time were they permitted to leave the ward. The subjects rested or

slept whenever they wished during the day, except for feeding and testing times; at night they were in bed by 11 o'clock. Records were kept of the quantity and quality of sleep. Brushing the teeth, shaving, showering, smoking, and chewing gum were prohibited during test periods.

Readings of temperature, barometric pressure, and relative humidity were taken regularly at 8 A.M., 12 Noon, and 8 P.M. The ranges of these readings were as follows:

Temperature:	70-85 degrees Fahrenheit
Barometric Pressure:	29.78" - 20.46" Hg
Relative Humidity:	65% - 88%

III Dietary Regimes

All food and fluid was carefully weighed, measured, checked, and charted. This included the reweighing of some items previously packeted and labelled for weight.

a. Standardization period:

The subjects were standardized for a preliminary seven day period on regular Army 10-in-1 Rations; during the last five days of this period, control clinical and laboratory data were collected. Equal servings of food were weighed for each man, with slight variations in biscuit and sugar intake to allow for differences in individual caloric requirements. The caloric intakes during this period ranged from 2500 to 3700 calories per day. Analysis of a typical subject-day's consumption of 10-in-1 Rations was as follows:

Carbohydrate:	330.9 Grams
Protein:	99.5 Grams
Fat:	96.1 Grams
Calories:	2654.0
Calcium:	464.0 Mg.
Iron:	24.2 Mg.
Vitamin A:	2242.0 Units
Vitamin B_1:	1606.0 Mcg.
Vitamin C:	73.1 Mg.
Vitamin B_2:	1316.0 Mcg.
Niacin:	16.3 Mg.
Sodium:	6.1 Gm.
Potassium:	2.9 Gm.

Water was taken ad libitum during the standardization period, the amount varying from 1800 to 2700 cc. per man per day.

b. Testing Period:

The testing periods ("deprivation") were ten days in length. Experimental Diets #9 and 10 were employed in August and September, 1945; Diets #11 and 12, in September and October.

The subjects were divided into two groups of five each in such a manner as to afford similar total weight and range of weight in each group. The groupings and detailed composition of the test rations are indicated in Table 4B.

TABLE 4B

COMPOSITION OF EXPERIMENTAL DIETS 9-12, INCLUSIVE

Diet #	Subjects	% CHO	% PROT.	% FAT	%MOISTURE	CAL.
9	C,K,E,P,B	86.1	---	9.3	4.6	856
10	J,D,A,H,M	75.4	9.7	9.2	5.7	846
11	C,K,E,P,B	75.8	---	10.0	14.2	790
12	J,D,A.H,M	68.3	9.2	10.0	12.5	816

As originally planned, Diets # 9 and 11 were to contain 90% carbohydrate and 10% fat, while Diets #10 and 12 were to contain 80% carbohydrate, 10% fat, and 10% protein; the caloric value of each then would have been 900. However, because of technical factors and resulting high moisture contents, the actual values attained are those listed in Table 4B. In all experiments subsequent to these, aberrations in percentual content and in caloric intake have been eliminated by determining moisture content first, then calculating percentual composition on the actual dry weight of the components.

The basic constituent materials of the present diets were:

Diet #9	"Charms" (Charms Co., Bloomfield, N.J.) Sucrose-lipid tablets (OQMG)
Diet #10	"Charms" Sucrose-lipid tablets Malted Milk tablets (Horlick)
Diet #11	Wheat Starch Honey Hydrogenated Fat
Diet #12	Wheat Starch Honey Hydrogenated Fat Powdered Dried Egg Albumin

It should be noted that Diets #9 and 10 consisted of properly weighed amounts of the listed constituents as previously prepared; diets #11 and 12, on the other hand, were baked into uniform biscuits by the Quartermaster laboratory in Chicago.

On each of the ten days of deprivation, every subject received 200 Gm. of test ration and 800 Gm. of tap water containing 1 Gm. NaCl. These were fed on the following schedule:

9 A.M. --	33	Gm.	ration	and	200	Gm.	Water
1 P.M. --	67	"	"	"	"	"	"
5 P.M. --	67	"	"	"	"	"	"
9 P.M. --	33	"	"	"	"	"	"

In addition, one multivatimin tablet per man per day was given at the 9 A.M. feeding. Each of these tablets contained:

Vitamin A -	2300 USP Units	- Fish Liver Oil
Vitamin D -	200 USP Units	- Viosterol
Vitamin B_1 -	1.0 mg.	- Thiamin Hydrochloride
Vitamin B_2 -	1.5 mg.	- Riboflavin
Vitamin C -	37.5 mg.	- Ascorbic Acid
	10.0 mg.	- Niacinamide

c. <u>Recovery Period</u>

Recovery from deprivation was carefully observed for five days. As in the preliminary standardization phase, the men were again fed Army 10-in-1 Rations. On the first recovery day, they were limited to 1200 calories of food and 2500 cc. of water; thereafter, calories and water were allowed to be taken <u>ad libitum</u>.

IV Laboratory Procedures

Fasting venous blood samples were drawn between 8:00 and 8:30 A.M., preceding the first morning feeding. Pre-sealed vacuumatic tubes were used to insure against contamination.

Urinary determinations were all made on aliquots of 24-hour collections covering periods from 8:00 A.M. of one day to 8:00 A.M. of the next. The specimens were preserved with toluene.

The following tests and procedures were carried out:*

1. Total Nitrogen in urine - Pregl, F., Die Quant. Organisch. Mikreansl., Berlin, 1923, 2nd ed. Brecher, A., Wien. Clin. Wech., 49:1228, 1936.

2. Urea Nitrogen in blood and urine - Van Slyke, D.D., and Cullen, C.E., J. Biol. Chem., 24:117, 1916.

3. Ammonia in blood and urine - idem.

4. Creatine and Creatinine in urine - Folin, O., Lab. Manual of Biol. Chem., 5th ed., D. Appleton-Century Company, New York, 1934.

5. Sodium in blood and urine - Barnes, R.B., Richardson, David, Berry, J.W., and Hood, R.L., Ind. and Eng. Chem., Analytic ed., 17:605-11, 1945.

6. Potassium in blood and urine - idem.

7. Chlorides in blood and urine - Van Slyke, D.D., and Sendroy, J., Jr., J. Biol. Chem., 58:523, 1923.

8. Depression of Freezing Point of urine - Beckmann, F., Zeit, phys. Chem., 2:653, 1888 (utilizing DeWar flask).

9. Routine Urinarlysis (specific gravity, sugar, albumin, acetone, discetic acid, microscopic examination)- Todd, D.C., and Sanford, A.H., Clinical Diagnosis by Lab. Methods, 9th ed., W.B. Saunders Co., Phila. 1941.

10. Complete Blood Count - idem.

* All colorimetric laboratory methods were slighly modified for use in the Drekter-Hoskins micro-colorimeter

11. Total Non-Protein Nitrogen in Blood - Folin, O., and Wu, H., J. Biol. Chem., 38:81, 1919.

12. Blood Sugar - idem, 41:367, 1920

13. Erythrocyte Sedimentation Rate and Hematocrit-Wintrobe, M.M., J. Lab. and Clin. Med., 15:287, 1939.

14. Circulation Time (Fluorescein) - Lange, K., and Boyd, L.J., Arch. Int. Med., 74:175, 1944.

15. Serum Proteins - Micro-Kjeldahl - Pregl, F., Die Quant. Organisch. Mikroanal., Berlin, 1923, 2nd ed.-Brecher, A., Wien. Clin. Wech., 49:1228, 1936.

16. Hepatic Function Tests (Icteric index, Van den Bergh, Cephalin Flocculation, Phosphorus, Alkaline Phosphatase, Total Cholesterol, Cholesterol Esters, Free Cholesterol, Albumen, Globulin) - all done on serum - Schwimmer, D., Klotz, S.D., Drekter, I.J., and McGavack, T.H., Am. J. Dig. Dis. 12:1, 1945.

17. Basal Metabolism Rate - using McKesson Water Metabolism Tester.

18. Electrocardiograms - using Cambridge Simpli-Trol.

19. Self-Rating on Clinical Symptoms: hunger, thirst, anorexia, nausea, vomiting, abdominal pain, diarrhea, constipation, headache, dizziness or lighheadedness, fatigue, muscle pain, insomnia, sleepiness, and general feeling of being below par. Each subject rated himself on each variable three times daily, once before each meal. A five-point numerical rating scale was used: 0-none; 1-mild; 2-moderate; 3-rather severe; and 4-extreme. The three ratings by an individual on a given variable were totaled to produce a score for the day on that variable. From this, group averages were obtained for each variable.

RESULTS

I Clinical Studies

1. General

At the end of ten days of deprivation, all the subjects were still ambulatory and alert. However, they were emotionally more irritable, physically weaker and more easily fatigued. Loss of weight and decrease of skin turgor were obvious.

Muscular pains did not occur in any group (see Laboratory Procedures -#19-page 12). This corroborated the findings in our earlier studies (Diets #6, 7, 8) where a supplement of NaCl had also been used, and was in sharp contrast with the severe pains noted when no salt was present in the dietary regime (Diets #1-5, inclusive). It appears certain that these muscular disturbances are a function of salt deficiency, and are not related to either caloric levels or to intrinsic dietary composition.

Headaches, varying from mild to severe ones, occurred in thirteen of the twenty subjects on the first day of deprivation, and in six on the second day. They were generally associated with moderate hunger, dizziness and weakness. After the second day, these symptoms occurred only sporadically and in mild form. It is significant that, on the first two days, these symptoms appeared chiefly about two or three hours after either the 9 A.M. or 1 P.M. feeding, and that they could be correlated with demonstrably low levels of glucose in the blood (see Laboratory Studies - Blood Sugar).

Hunger was not an outstanding complaint. In all four groups it was generally mild from the second to eighth day, then increased slightly during the ninth and tenth days. Thirst likewise presented no great problem. There was a moderate accentuation during the fourth to eighth days of deprivation, but this diminished during the last two days. With Groups #9 and 10, thirst was slightly more pronounced than with #11 and 12, probably because of the greater perspiratory and respiratory water losses sustained because of hot weather.

Sleepiness and a "feeling of being below par" were present in a small degree throughout, but to the least extent with Diet #12.

Bowel habits were not seriously disturbed in any group during deprivation. The stools were somewhat smaller than normal, and increased temporarily to 2-4 daily on the fourth and fifth days in five subjects. Flatulence and abdominal discomfort were negligible. Nausea and vomiting occurred once, in Subject A, on Diet #9 during the first day of deprivation, but not thereafter.

2. Weight Changes - Tables 5A, 5B, 8A, 8C: Figures 10, 10A, 10B, 23, 23A, 23B

The subjects on diets containing protein sustained greater losses of weight than did their companions who were simultaneously eating protein-free diets. This increase in weight loss was less with egg white than with malted milk. The men on Diet #10 (malted milk) lost an average of 5.4 Kg.* in 10 days, or 0.5 Kg. more than those on Diet #9, while those on the egg white regime (Diet #12) lost only 0.3 Kg. more than did those on Diet #11.

The rate of weight loss was greatest during the first two days, ranging from 0.8 to 1.3 Kg. per day, then diminished somewhat during the third to fifth days. After the fifth day, the rate of loss was considerably less. The rapid loss of weight during the first five days could be accounted to loss of fluid - both urinary and perspiratory - rather than to wasting of tissue substance.

3. Basal Metabolic Rates

Neither deprivation per se nor the intrinsic composition of any diet produced any consistent change in the basal metabolic rate of any subject. Within the same dietary group there could be found individuals exhibiting no change, as well as others with either increases or decreases.

4. Cardiovascular Changes

Pulse rates in practically all subjects slowed by five to twenty-five beats per minute after the fourth or fifth day of deprivation.

* First-day and cumulative losses of weight during deprivation have been calculated from the figure for the last control day, rather than from an average of all control days.

No specific directional trends or dietary correlations could be established with readings of blood pressure or pulse pressure.

Prolongations of circulation time (done by the fluorescein method)* were present in more than half of the subjects, more notably in the arm-to-leg circulation than in the arm-to-lip time. These delays in peripheral circulation bore no obvious relation to dietary composition or to changes in pulse rate, but they could definitely be correlated with changes in the electrocardiogram.

Electrocardiographic changes were noted in 15 of the 20 subjects. These consisted chiefly of diminution in the height of the T-wave in Leads I and II; the degree of T-wave lowering ranged from 1.0 to 4.0 mm., with resulting amplitudes as low as 0.0 to 1.0 mm. in some instances. Prolongations of the Q-T segment by 0.04 to 0.08 seconds were also noted, but these always paralleled the slowing of the pulse rate.

A more detailed analysis of cardiovascular alterations and their possible causes will be provided in a future report, which will include data covering a series of over 25 diets and 100 subjects.

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* We are indebted to Drs. Kurt Lange and David Weiner, who gave generously of their time to make the measurements of circulation time.

II Laboratory Studies

1. Urinary Volume - Tables 5A, 5B, 8A, 8C: Figures 11, 24.

Comparison of the paired protein-free and protein-containing diets reveals that:

a. During the whole ten-day period, the malted milk ration produced 969 cc. more urine than did its companion protein-free regime.

b. With dried egg white, this difference amounted to only 208 cc.

c. If only the last five days of deprivation are considered, the increase in urinary volume with malted milk protein was 684 cc., whereas with egg white there were actually 19 cc. less excreted than with the simultaneously-run control.

Utilization of the last five days of deprivation for comparison is of distinct value, since it reflects directly the solute-producing quality of the experimental diet, and since it excludes the high urinary volumes seen during the first several days. The latter are partially a carry-over and reflection of the state of hydration existing before deprivation.

That the urinary volumes with control Diets 9 and 11 differ is not due to individual variations in the subjects, since the same subjects served in both groups. Rather, the lower overall levels observed with Diets #9 and 10 can definitely be ascribed to distinctly greater perspiratory water losses, since they were tested during a particularly hot and humid period. Such an environmental cause of variation could be eliminated only by providing completely air-conditioned housing.

As will be detailed later, a direct correlation exists between increases in urinary output and increases in total urinary solutes and nitrogen.

In these studies, as in the earlier ones on Diets 1-8, inclusive, the actual urinary volumes consistently exceeded the theoretical minimum as calculated from Dr. James L. Gamble's factor 1.4 (2). This disparity

is due to the fact that our subjects rarely produced urine with a concentration above 1.2 osmols per liter. A detailed analysis of renal concentrating capacity, with demonstrable variations on different dietary regimes, will be given in a forthcoming report.

2. Urinary Solutes - Tables 5A, 5B, 8A; Figures 11A, 25.

The solute content of the urine (in milliosmols) was calculated from figures for the depression of the freezing point according to the equation:

$$\text{Total Milliosmols} = \frac{\text{Depression of Freezing Point}}{1.86} \times \text{Urine Volume (cc.)}$$

As might be anticipated, the presence of protein in the diet increased the amount of urinary solutes. This effect, however, was much more pronounced with malted milk protein than with egg white. The average daily total solute output for the ten-day experiment with malted milk exceeded by 170 milliosmols the average for its paired protein-free control diet. With dried egg white, the daily difference was only 63 milliosmols.

If only the last five experimental days are utilized for comparison, the protein-no protein differences amount to 175 and 48 milliosmols, respectively, for malted milk and egg white, further emphasizing the greater retention of egg white.

3. Nitrogenous Substances in Urine - Tables 5A, 5B, 8B, 8D; Figures 12-15, inclusive, and 26-29, inclusive.

a. Total Nitrogen in Urine - Figures 12, 12A, 26, 26A.

Deprivation produced a decrease in the output of total urinary nitrogen. The greatest rate of drop occurred during the first two days.

Retention of the egg albumin exceeded that of the malted milk protein. With malted milk, the average daily total urinary nitrogen during deprivation was 9.4 Gm., or 67.7 percent of the standardization

period average; with egg white, it was 6.8 Gm., or 58.5%. Stated in another way, the men on the malted milk ration excreted 2.6 Gm. more nitrogen than did the group ingesting no protein. With egg white, this difference was only 1.5 Gm.

If nitrogen balances are set up, it is apparent that nitrogen equilibrium is not attained with either type of protein. This may be due to the relatively small amounts of nitrogen fed daily, namely 3.05 Gm. in Diet #10, and 2.90 Gm. in Diet #12. However, the degree of negative nitrogen balances is certainly less marked with egg white than with malted milk. In the former case, it was minus 3.90 Gm.; in the latter, minus 6.35 Gm.

b. Urea Nitrogen in Urine

The urinary content of urea nitrogen consistently paralleled that of total nitrogen. It comprised 84% - 95% of the latter.

c. Creatinine in Urine - Figures 13, 27.

Variations in urinary creatinine bore no relationship to dietary composition. In all instances there was a drop from the normal standardization range of 900 - 1200 mg. to 700 - 900 mg. per 24 hours. The lowest levels were reached on the fourth and eighth days of deprivation.

d. Creatine in Urine - Figures 14, 28

Phasic variations were present in the urinary excretion of creatine. Peaks of creatine output were reached on the fourth day, then again on the sixth or seventh day.

The levels of creatinuria bore no demonstrable relationship to the dietary content of protein, to the urinary nitrogen, or to the excretion of potassium. It is clear that the conditions of deprivation *per se*, rather than dietary composition, were responsible for the fluctuations. An elucidation of the precise mechanisms operative here awaits further study. It does seem apparent, however, that the classic concept that creatinuria is a measure of endogenous protein metabolism is untenable.

c. Ammonia Nitrogen in Urine - Figures 15, 29

The amount of ammonia nitrogen in the urine decreased until the fourth day of deprivation. Thereafter, a stabilized low level was maintained,

It is of some interest to note that with Diet #10, the ammonia nitrogen excretions averaged 7-10 milliequivalents per day less than with the other three diets. This occurred despite the fact that two men (Subjects A and D) in that dietary group exhibited positive acetone in the urine on various occasions (see Acetone in Urine), with no increase in their individual urinary ammonia output, It is possible that the base-forming capacity of the kidney was somewhat curtailed as part of a general diminution of renal function.

4. Specific Gravity of Urine

The specific gravity of the urine varied from 1.005 to 1.031. The highest specific gravities occurred during the fourth and fifth days of deprivation, then again on the ninth or tenth day.

Every subject, at one time or another during deprivation, was able to concentrate to 1.020 or higher. With Diets #11 and #12 (which represented the second experimental run for the same subjects) the overall specific gravities were 0.005 to 0.010 lower than with Diets #9 and #10. This lowering paralleled decreases in solute load.

5. Coagulable Protein and Formed Elements in the Urine.

In the first experimental run (Diets #9 and #10), small traces of albumen were found in the urine of nine subjects; a heavy trace occurred with one man (Subject E). The albuminuria usually made its first appearance on the fourth or fifth day, then disappeared, and frequently reappeared on the eighth to tenth days. It was almost invariably associated with the microscopic finding of erythrocytes and leukocytes, and -- in seven cases -- with the presence of hyaline and granular casts.

During the second experiment, three men on Diet #11 (Subjects E,K,P) exhibited small traces of albumen, but only on the eighth or ninth day; subject E alone also excreted erythrocytes. On Diet #12, subject A spilled albumen and a few red blood cells on the tenth day.

It is clear that the albuminuria and microscopic hematuria here seen are not causally related to dietary composition or to the presence of protein. Rather, they appear to be a function of dehydration coupled with solute load on the kidney. That albumen and formed elements were seen less often in the second experimental run is likely due to the smaller perspiratory water losses and to the consequently smaller degree of dehydration present. It is highly debatable whether successive exposures to deprivation can produce any bodily accomodation to dehydration.

As mentioned in our earlier report on Experimental Diets #1 to 8, inclusive, it is probable that limitations of water intake can activate a previously unsuspected latent diminution in renal reserve.

6. Sugar and Acetone Bodies in Urine

Analyses made for sugar and acetone bodies in the 24-hour collections of urine produced rather unexpected results. In the first experiment, no reducing substances were found at any time in the urine of any subject. Nevertheless, Subject A (Diet #10) exhibited traces of acetone on the second, third, fifth, seventh, and tenth days of deprivation; Subjects D (Diet #10) and P (Diet #9) spilled traces on the ninth day. Diacetic acid was consistently absent.

In the second experiment, however, four of the five men on Diet #11 had from a very slight trace to as much as 1.0% sugar in the urine throughout the ten-day period; the fifth man had glycosuria for nine days. On Diet #12, four subjects exhibited very slight reduction on five different days, one on three days. One man on Diet #11 (K) had mild acetonuria on the tenth day, while two men (A, H) showed it on the eighth day. Diacetic acid again was not found at any time.

It is difficult to offer a simple explanation for these phenomena. The acetonuria may be a function of partial starvation and dehydration (although it is to be recalled that none occurred with our earlier experimental diets offering only 400-525 calories.)

The glycosuria, heavier and more frequent on the protein-free Diet #11 than on the protein-containing Diet #12, may be a function of hyperglycemic peaks (see section on Blood Sugar), but it is reasonable to have expected the same phenomena in similarly related degrees with the comparable Diets #9 and 10. It is possible that the sudden appearance of reducing substances in the urine during the second experimental run represents evidence of selective renal disturbance.

7. <u>Total Non-Protein Nitrogen and Urea Nitrogen in the Blood</u> - Tables 6A, 6B, 9A, 9C; Figures 16, 30

There was a moderate increase in the total non-protein nitrogen and urea nitrogen in the blood during deprivation. This rise was progressive, and was more marked with Diets #9 and #10 than with #11 and #12. The changes were unrelated to the presence or absence of protein in the diet. The differences between the two experimental runs can be attributed to moderate variations in electrolyte patterns occasioned by greater salt losses in sweating.

Despite the rises in the levels of nitrogenous substances in the blood, no symptoms or signs of uremia were encountered at any time.

8. <u>Blood Sugar</u> - Tables 6A, 6B, 9A, 9C

Fasting blood sugar levels observed in the morning followed no specific directional pattern. The variations could not be correlated with dietary content.

However, clinical symptoms of hypoglycemia were noted two to three hours <u>after</u> the 9 A.M. and 1 P.M. feedings during the first two days of deprivation (see <u>Clinical Studies</u> - <u>1. General, page 13.</u>) These

were first observed with Diets #9 and #10; therefore; when Diets #11 and #12 (associated with similar symptoms) were tested later, hourly determinations were made of the level of theblood sugar from before the first feeding to mid-afternoon of the first day of deprivation.

Following the morning feeding, only mild rises (12-36 mg. per 100 cc.) were noted; these occurred in six of the ten subjects on both Diets #11 and #12. Secondary drops of 18-42 mg. were noted in seven of the ten men within an hour after the earlier peak had been reached.

After the 1 P.M. meal (containing 67 Gm. food in contrast with 33 Gm. in the morning), the blood sugar values rose more sharply. With Diet #11 (no protein), all the subjects were affected; the increases ranged from 32 to 90 mg., with the highest absolute level reached being 160 mg. per 100 cc. With Diet #12 (10% protein), only two subjects (A, J) showed significant rises; these were 34 and 58 mg., respectively, with the highest absolute level here being 114 mg. per 100cc.

The secondary fall following these post-prandial afternoon rises was sharper and more marked than it had been in the morning. The greatest changes occurred with the protein-free Diet #11, on which three men (E,K,P) exhibited drops in blood sugar of 88, 54, and 40 mg., respectively. With Diet #12, the range of fall was only 18 to 32 mg.

In the early phases of deprivation there appears to exist a lability in the levels of blood sugar of sufficient degree to produce clinical manifestations of hypoglycemia. These reactive hypoglycemic episodes are more apt to occur with larger feedings, which tend to produce higher initial post-prandial levels; the higher the level, the more insulin is mobilized, hence the sharper the secondary drop. The presence of protein in the diet appears to minimize these hypoglycemic effects.

9. Serum Cholesterol - Tables 6A, 6B, 9A, 9C; Figures 21, 35

In all groups there was a general tendency for serum cholesterol levels to rise to a plateau 30-70 mg. per 100 cc. above control levels during the first 5-7 days of deprivation. Thereafter, there was a gradual

drop towards normal. During the first several days of the recovery period, there was a slight temporary dip below normal. The percentage of cholesterol esters remained undisturbed throughout.

These changes in total cholesterol are of the type frequently seen when the intake of food is suddenly decreased.

Other tests mirroring hepatic function - the icteric index, Van den Bergh, cephalin-cholesterol flocculation, and alkaline phosphatase - did not deviate from the normal.

10. <u>Serum Proteins</u> - Tables 6A, 6B, 9B, 9D; <u>Figures 22, 36</u>

A moderate but definite rise in total serum proteins occurred during the first 3-4 days of deprivation. Thereafter the levels remained about normal. During the first several days of the <u>recovery</u> period, the serum protein concentrations fell somewhat below standardization values, but by the fifth day of recovery, normal levels were again being attained. The albumen:globulin ratios were well maintained at all times.

All the experimental dietary groups behaved similarly with respect to these changes in serum proteins. The variations observed can be attributed to homoconcentration and homodilution occasioned by the conditions of the experiment. The homodilution effect is especially apparent during the recovery phase, when the water intake was sharply increased.

11. <u>Electrolytes - Sodium, Potassium, Chlorides</u> - Tables 5A, 5B, 6A, 6B, 7A, 7B, 8A, 8C, 9A, 9C, 10A, 10B; Figures 17, 17A, 18, 18A, 19, 19A, 31, 31A, 32, 32A, 33, 33A.

a. <u>Serum Concentrations of Sodium, Potassium and Chlorides</u>

Variations in serum concentrations of sodium, potassium, and chlorides moved in similar directions with each of the four dietary groups here utilized.

<u>Serum sodium</u> levels remained within normal ranges for the first three days of deprivation, then (continued)

gradually diminished by 5-9 milliequivalents during the remainder of the experimental period.

Serum potassium values rose 4-5 milliequivalents during the first half of deprivation, then dropped slowly. Completely normal levels were reached by the fifth recovery day.

Serum chloride readings tended to drop slightly during the first 4-5 days, then reverted towards normal.

b. Urinary Excretion of Sodium, Potassium, and chlorides.

The urinary excretion patterns for sodium, potassium, and chlorides were similar for Diets #9, 11, and 12. Diet #10, however, differed from the others in having significantly higher urinary levels of all three electrolytes.

Urinary sodium excretions decreased precipitously during the first 3-5 days in all groups. Thereafter, with Diets #9, 11, and 12, there was a gradual stabilization at 12-20 milliequivalents per day. With Diet #10, however, the lowest figure reached was 37 milliequivalents on the third day; thereafter there was a gradual increase to 57 milliequivalents, resulting in daily differences of 10-41 milliequivalents over its companion Diet #9.

Urinary potassium figures exhibited a moderate downward trend during the first five days with Diets #9, 11, and 12. With Diet #10, on the other hand, the fourth day saw the beginning of a plateau whose values exceeded those during the control period; these fell slightly in the last three days.

Urinary Chlorides dropped sharply in the first three days, paralleling closely the course of urinary sodium. Here again, the values obtained for Diet #10 exceeded those for Diet #9 after the fourth day by 11-25 milliequvalents.

These differences in the urinary outputs of the three electrolytes with Diet #10 can be attributed to an increased intake of sodium present in the malted milk. This amounted to 0.81 Gm. daily, in comparison with 0.4, 0.4, and 0.6 Gm., respectively, for Diets #9, 11, and 12.

The relative uniformity of the four diets with respect to serum concentrations of electrolytes, and the variation in urinary excretions with Diet #10, emphasize the importance of electrolytes; also, they highlight the body's tendency to maintain the internal environment as stable as possible.

DISCUSSION

The data herein reported leave many questions still unanswered concerning protein and nitrogen metabolism on limited fluid and food intake. The complexity of the problem is directly related to the complexity of the human organism, and involves studies of endocrine balance, electrolyte patterns, carbohydrate metabolism, circulatory involvement, and renal function.

Some of these problems have already been investigated in studies completed, but as yet unreported. Others are projected for the near future. When a large series of studies has been made, valid overall conclusions will more easily be able to be drawn.

References

1. (a) Swanson, Pearl: Project Report #3, Committee on Food Research, OQMG

(b) Allison, James B.: Project Reports #1, 2, 3, Committee on Food Research, OQMG

2. Gamble, James L.: Proc. Am. Philosoph. Soc., 88: 153, 1944

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WELFARE ISLAND, NEW YORK CITY

GROUP AVER. DIET 9
CHO 90%
FAT 10%

TABLE 5A

24 HOUR URINE COLLECTION

Day		Weight (kg)	Water Intake (cc)	Volume Output (cc)	Minimal Urine Volume (cc)	Depr. F.Pt. degree cent.	Total Milli-osmols	Sodiun (gm)	Potass. (gm)	Chlorides (gm)
Control Aver.		72.1	1822	1190	740	1.72	1041	4.46	2.94	12.52
Deprivation	1	71.0	800	1158	490	1.21	685	2.95	2.80	7.81
	2	69.9	800	489	297	1.61	417	1.18	1.82	3.47
	3	69.3	800	317	229	1.90	321	0.62	1.62	1.99
	4	68.3	800	306	232	1.97	324	0.56	2.00	1.48
	5	67.7	800	338	224	1.98	315	0.35	2.44	1.02
	6	67.5	800	327	243	1.95	341	0.63	2.40	0.99
	7	67.5	800	352	251	1.89	353	0.41	2.38	0.71
	8	67.6	800	376	270	1.87	375	0.37	1.98	0.85
	9	67.4	800	384	244	1.68	342	0.38	1.88	0.62
	10	67.2	800	385	231	1.60	324	0.36	1.74	0.40
Recovery										
	1	67.6	2195	650	318	1.41	446	0.53	2.34	0.74
	2	68.7	2260	690	507	1.73	632	0.56	1.66	2.41
	3	69.7	2565	842	525	1.62	755	2.61	1.76	4.61
	4	70.4	2558	1090	624	1.40	874	4.36	1.98	12.24
	5	70.2	2384	1535	579	1.47	803	6.03	2.34	13.42

(continued)

GROUP AVER. - DIET 9
CHO - 90%
FAT - 10%

TABLE 5B

24 HOUR URINE COLLECTION

Day		Total Nitrogen	Urea Nitrogen	NH_3 Nitrogen	Creatine	Creatinine
		(gm)	(gm)	(gm)	(gm)	(gm)
Control Aver.		13.10	11.63	0.79	0.02	1.05
Deprivation	1	9.25	8.35	0.57	0.05	0.75
	2	6.75	6.16	0.45	0.12	0.86
	3	5.57	4.69	0.39	0.20	0.74
	4	6.00	5.16	0.37	0.20	0.78
	5	6.06	5.03	0.36	0.15	0.80
	6	6.07	5.56	0.55	0.04	0.87
	7	7.13	6.19	0.39	0.20	0.83
	8	7.53	5.79	0.38	0.20	0.78
	9	7.27	5.88	0.39	0.14	0.77
	10	6.74	5.37	0.43	0.15	0.79
RECOVERY	1	9.46	7.90	0.56	0.16	0.84
	2	12.38	10.46	0.59	0.28	0.87
	3	12.15	9.80	0.67	0.10	0.88
	4	10.70	8.26	1.07	0.04	0.83
	5	12.03	10.46	0.73	0.03	0.87

(continued)

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WELFARE ISLAND, NEW YORK CITY

GROUP AVER. - DIET 10
CHO - 80%
PROT. - 10% (Milk Protein)
FAT - 10%

TABLE 5C

24 HOUR URINE COLLECTION

Day	Weight (kg.)	Water Intake (cc.)	Volume (cc.)	Minimal Urine Volume (cc.)	Depr. Fr.P. (Degr Cent.)	Total Milli-osmols	Sodium (gm.)	Potass. (gm.)	Chlorides (gm.)
Control Aver.	72.1	1840	1100	744	2.02	1085	4.38	2.96	12.23
DEPRIVATION 1	71.0	800	803	627	1.76	878	3.06	2.48	7.53
2	70.1	800	670	647	1.70	600	1.77	2.06	4.67
3	69.0	800	450	335	1.94	470	0.91	2.30	2.25
4	68.1	800	472	326	1.78	455	0.86	3.20	1.53
5	67.6	800	498	362	1.88	506	0.84	4.12	1.75
6	67.4	800	493	385	1.92	510	1.07	4.10	1.64
7	67.0	800	513	381	1.93	531	1.02	4.30	1.37
8	66.9	800	488	365	1.94	510	1.10	3.26	1.73
9	66.7	800	534	392	1.95	548	1.20	3.68	2.09
10	66.7	800	480	363	1.97	509	1.30	3.20	1.60
RECOVERY									
1	67.8	2460	539	425	2.01	595	1.19	3.48	1.76
2	69.2	2650	738	411	1.85	730	1.11	3.50	2.75
3	70.1	2900	812	547	1.85	794	2.77	2.14	6.42
4	70.6	2230	1095	596	1.54	890	4.66	1.98	10.10
5	70.5	2420	1242	696	1.52	975	6.06	2.22	13.05

GROUP AVER. - DIET 10
CHO - 80%
PROT - 10% (Milk Protein)
FAT - 10%

TABLE 5D

24 HOUR URINE COLLECTION

Day	Total Nitrogen	Urea Nitrogen	NH_3 Nitrogen	Creatine	Creatinine
	(gm)	(gm.)	(gm.)	(gm.)	(gm.)
Control Aver.	13.88	12.61	0.85	0.02	1.06
Deprevation					
1	10.00	9.22	0.47	0.04	0.89
2	10.02	9.45	0.47	0.12	0.88
3	8.38	7.23	0.33	0.19	0.81
4	8.40	6.55	0.33	0.22	0.69
5	9.24	7.90	0.27	0.14	0.89
6	9.30	8.17	0.26	0.04	0.88
7	9.90	8.69	0.25	0.20	0.83
8	9.20	7.17	0.24	0.16	0.76
9	10.13	8.40	0.27	0.13	0.81
10	9.46	7.98	0.28	0.19	0.78
RECOVERY					
1	11.70	10.05	0.42	0.24	0.90
2	14.05	12.13	0.56	0.34	0.79
3	12.73	10.28	0.68	0.16	0.87
4	9.83	7.50	1.23	0.03	0.92
5	11.26	8.94	1.09	0.02	0.90

(continued)

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(continued)
RESTRICTED

GROUP AVER. - DIET 9
CHO - 90%
FAT - 10%

TABLE 6A

FASTING BLOOD

Day		Sodium	Potassium	Chlorides	Sugar	NPN	UN	Total Chol.
Control Aver.		329	12.4	620	80.3	34.2	16.7	169
Deprivation	1							
	2	330	13.6	603	79.9	35.0	17.1	221
	3	330	14.3	596				235
	4	325	14.5	580	83.0	41.4	21.4	230
	5	327	20.8	599				230
	6	323	32.2	615				235
	7	320	30.2	624	89.6	48.4	24.0	227
	8	320	26.7	604	76.5	51.9	25.6	208
	9	324	23.5	600				189
	10	324	23.5	596	83.4	53.0	26.5	178
Recovery	1	324	23.7	599				152
	2	325	20.9	612	78.6	32.8	15.9	147
	3	328	15.7	614				149
	4	331	14.0	616	70.6	30.4	15.4	149
	5	332	11.8	629				160

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(continued)

GROUP AVER.- DIET 9
CHO - 90%
FAT - 10%

TABLE 6B

FASTING BLOOD

Day	TSP	ALB	Glob.	A/G	Hemat.	RBC	HCB
Control Aver.	7.3	5.3	2.0	2.7	43	4.50	15.0
D 1					44	4.54	15.7
e 2	7.9	5.7	2.2	2.7	41	4.14	14.6
p 3	7.9	5.7	2.2	2.7	41	4.10	14.8
r 4	7.7	5.5	2.1	2.6	42	4.02	14.4
i 5	7.5	5.4	2.1	2.6	41	4.01	14.6
v 6	7.7	5.5	2.2	2.6			14.7
a 7	7.4	5.4	2.1	2.6			
t 8	7.3	5.2	2.0	2.8	43	4.36	15.2
i 9	7.1	5.1	2.0	2.6	40	4.05	15.7
o 10	7.1	5.1	2.0	2.6	42	4.62	16.5
n							
Recovery							
1	6.8	5.0	1.8	2.7	39	4.49	16.2
2	6.6	4.7	1.8	2.6	35	4.42	15.9
3	6.4	4.6	1.8	2.6			13.7
4	6.6	4.8	1.9	2.6	38	4.43	14.6
5	7.0	5.1	1.9	2.7		4.63	15.2

GROUP AVER. - DIET 10
CHO - 80%
PROT - 10% (Milk Protein)
FAT - 10%

TABLE 6D

FASTING BLOOD

Day	TSP	ALB.	GLOB.	A/G	Hemat.	RBC	HGB
Control AVER	7.6	5.5	2.1	2.7	44	4.59	15.4
Deprivation 1					42	4.32	15.2
2	7.9	5.7	2.1	2.7	43	4.01	15.0
3	8.3	6.1	2.2	2.8	42	4.01	14.5
4	8.4	6.2	2.2	2.8	44	4.11	14.6
5	8.1	6.0	2.1	2.9	43	4.04	14.6
6	8.1	6.0	2.1	2.7			15.2
7	7.9	5.6	2.1	2.7			
8	7.3	5.2	2.0	2.6	47	4.09	16.1
9	7.7	5.7	2.1	2.7	43	4.20	16.0
10	7.0	5.1	1.9	2.7	43	4.37	16.2
RECOVERY 1	6.9	5.0	1.9	2.6	40	4.08	15.5
2	6.6	4.8	1.8	2.7	37	4.27	15.5
3	6.5	4.8	1.8	2.7			14.2
4	6.6	4.9	1.8	2.7	40	4.25	14.4
5	7.0	5.1	1.9	2.6		4.36	14.9

(continued)
RESTRICTED

GROUP AVER. - DIET 9
CHO - 90%
FAT - 10%

TABLE 7A

TOTAL MILLI-EQUIVALENTS

Day	Sodium Urine	Sodium Blood	Potassium Urine	Potassium Blood	Chlorides Urine	Chlorides Blood	NH_3 Nitrogen Urine
Control Aver.	194	143	76	3.17	216	105	56
Deprivation 1	123		72		135		41
2	78	144	48	3.48	60	102	32
3	27	144	42	3.66	34	101	28
4	25	141	52	3.71	26	99	27
5	15	142	64	5.33	18	102	26
6	28	140	62	8.24	17	104	39
7	18	139	62	7.73	12	106	28
8	16	139	52	6.03	15	102	27
9	17	141	48	6.02	11	102	28
10	16	141	46	6.02	9	101	31
RECOVERY 1	23	141	60	6.06	13	102	40
2	24	141	42	5.35	42	104	42
3	113	143	46	4.01	79	104	48
4	190	144	52	3.58	212	105	77
5	274	145	60	3.02	233	107	52

GROUP AVER. - DIET 10
CHO - 80%
PROT 10% (Milk Protein)
F/T 10%

TABLE 7B

TOTAL MILLI-EQUIVALENTS

Day	Sodium Urine	Sodium Blood	Potassium Urine	Potassium Blood	Chlorides Urine	Chlorides Blood	NH3 Nitrogen Urine
Control Aver.	194	145	76	3.54	212	104	61
Deprivation 1	153		64		130		34
2	77	144	54	4.22	81	103	24
3	40	143	60	4.56	39	101	24
4	37	141	82	5.07	26	99	19
5	37	140	106	5.45	30	99	19
6	47	140	108	8.95	28	107	19
7	45	137	110	7.33	24	105	18
8	48	140	84	6.85	30	111	17
9	52	139	94	6.59	36	103	19
10	57	138	82	6.43	28	103	20
Recovery 1	52	140	90	6.38	30	103	30
2	48	141	90	5.55	47	104	40
3	120	144	54	4.04	111	105	49
4	202	144	50	3.79	174	104	88
5	266	144	56	3.43	225	104	78

GROUP AVER. - DIET 10
CHO - 80%
PROT - 10% (Milk Protein)
FAT - 10%

TABLE 6C

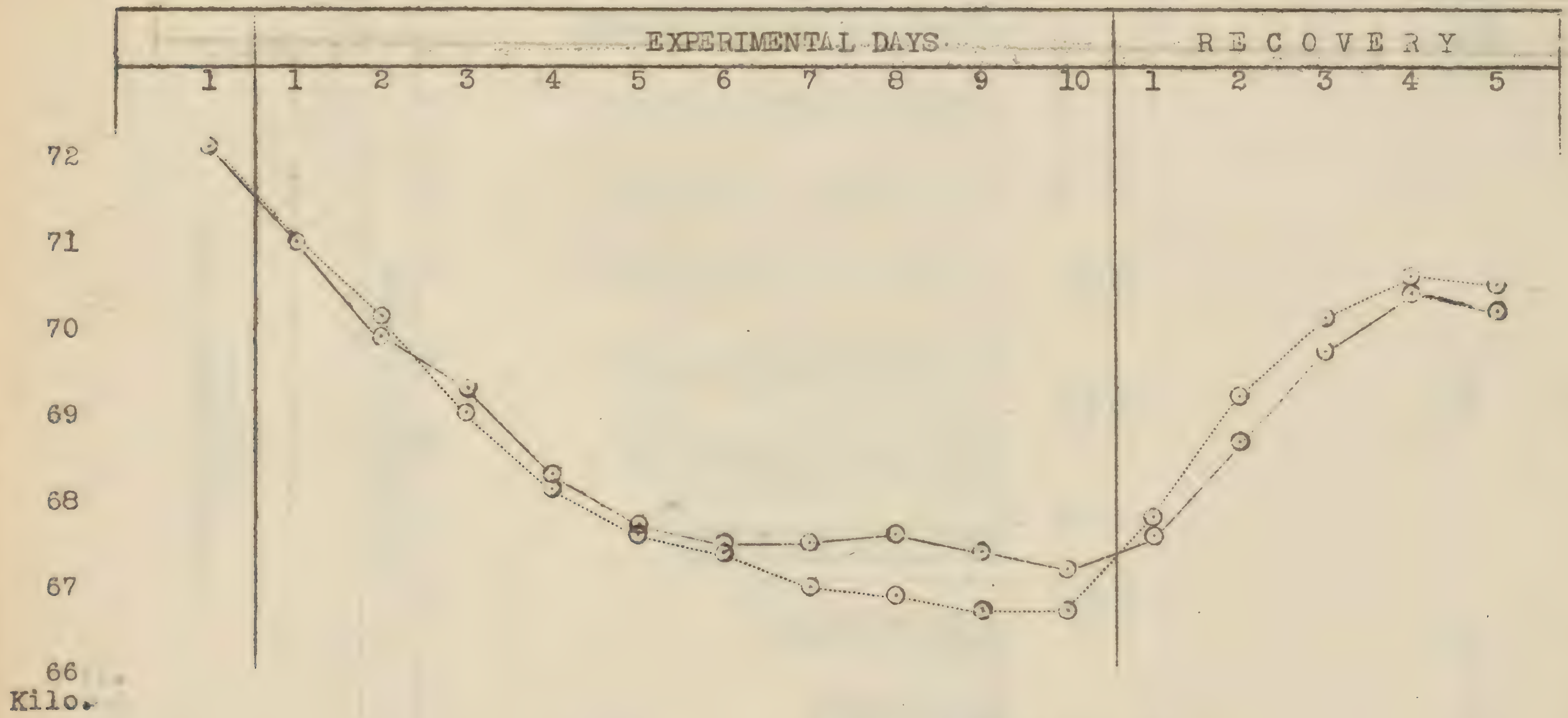
FASTING BLOOD

Day	Sodium	Potassium	Chlorides	Sugar	NPN	UN	Total chol.
Control Average	333	13.7	612	78.3	35.1	17.1	172
Deprivation 1							
2	331	16.5	605	75.9	34.5	16.6	238
3	329	17.8	593				244
4	325	19.8	583	79.0	37.7	18.8	229
5	321	21.5	585				227
6	321	34.9	631				239
7	316	28.6	617	85.6	45.7	23.0	251
8	321	26.7	652	71.3	50.3	24.7	205
9	320	25.7	608				205
10	318	25.1	605	77.3	51.3	25.5	179
RECOVERY 1	323	24.9	606				165
2	325	21.5	615	74.6	32.4	15.7	137
3	332	15.8	622				129
4	331	14.8	616	78.8	29.5	15.0	142
5	332	13.5	614				158

(continued)
RESTRICTED

FIGURE 10

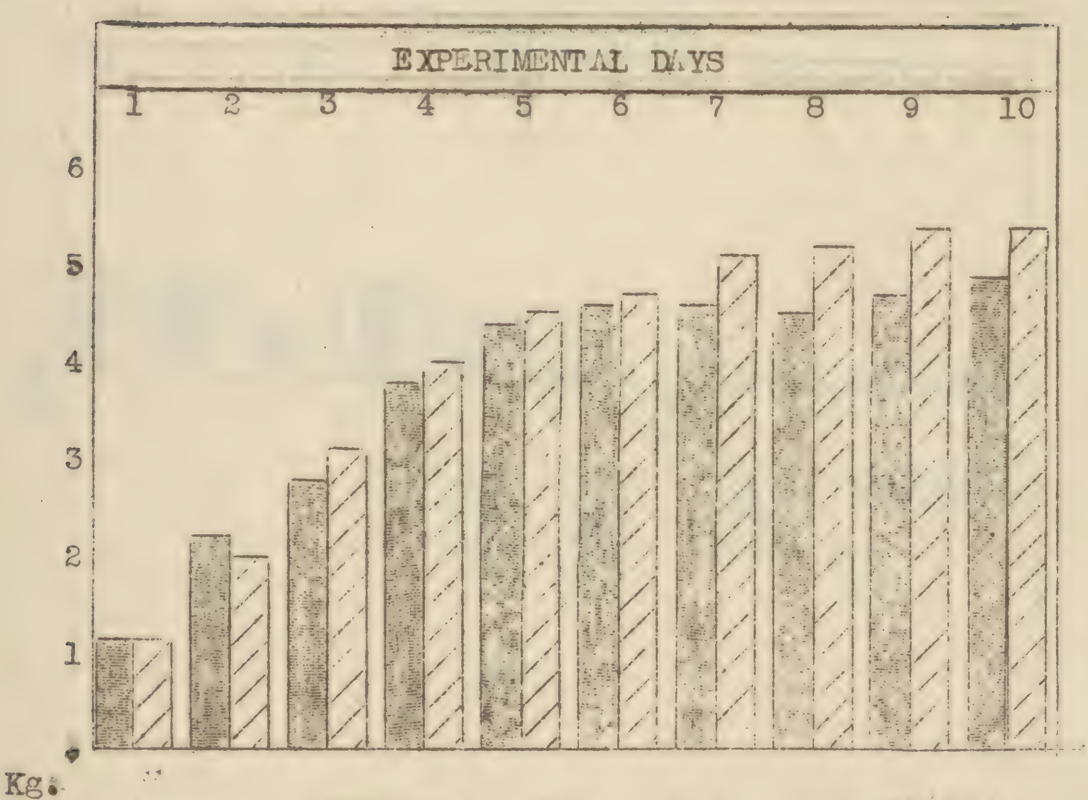
DAILY WEIGHT RECORD
(Kilograms)



DIET NO.	CHO.	FAT	Milk Prot.
—— 9	90%	10%	
········ 10	80%	10%	10%

FIGURE 10A

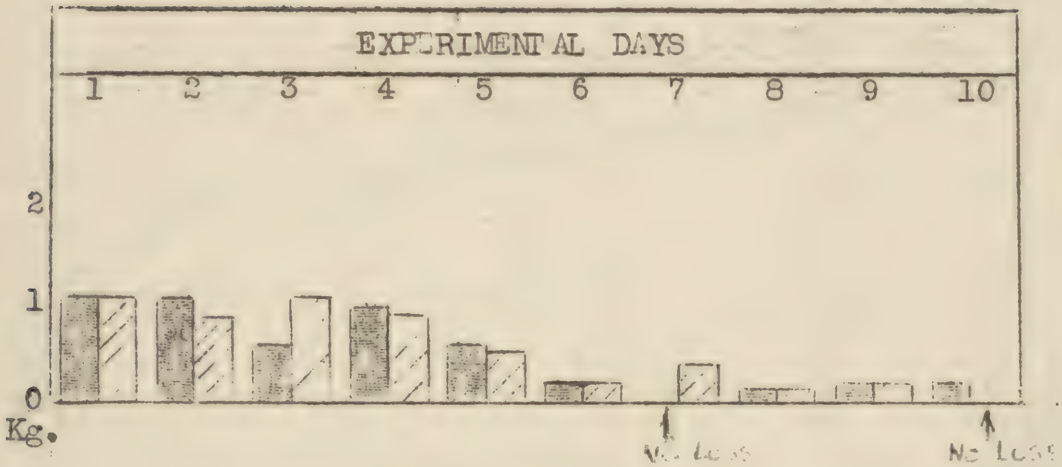
CUMULATIVE WEIGHT LOSS
(Kilograms)



DIET NO.	CHO.	FAT	PRO. (Milk)
9	90%	10%	
10	80%	10%	10%

FIGURE 10B

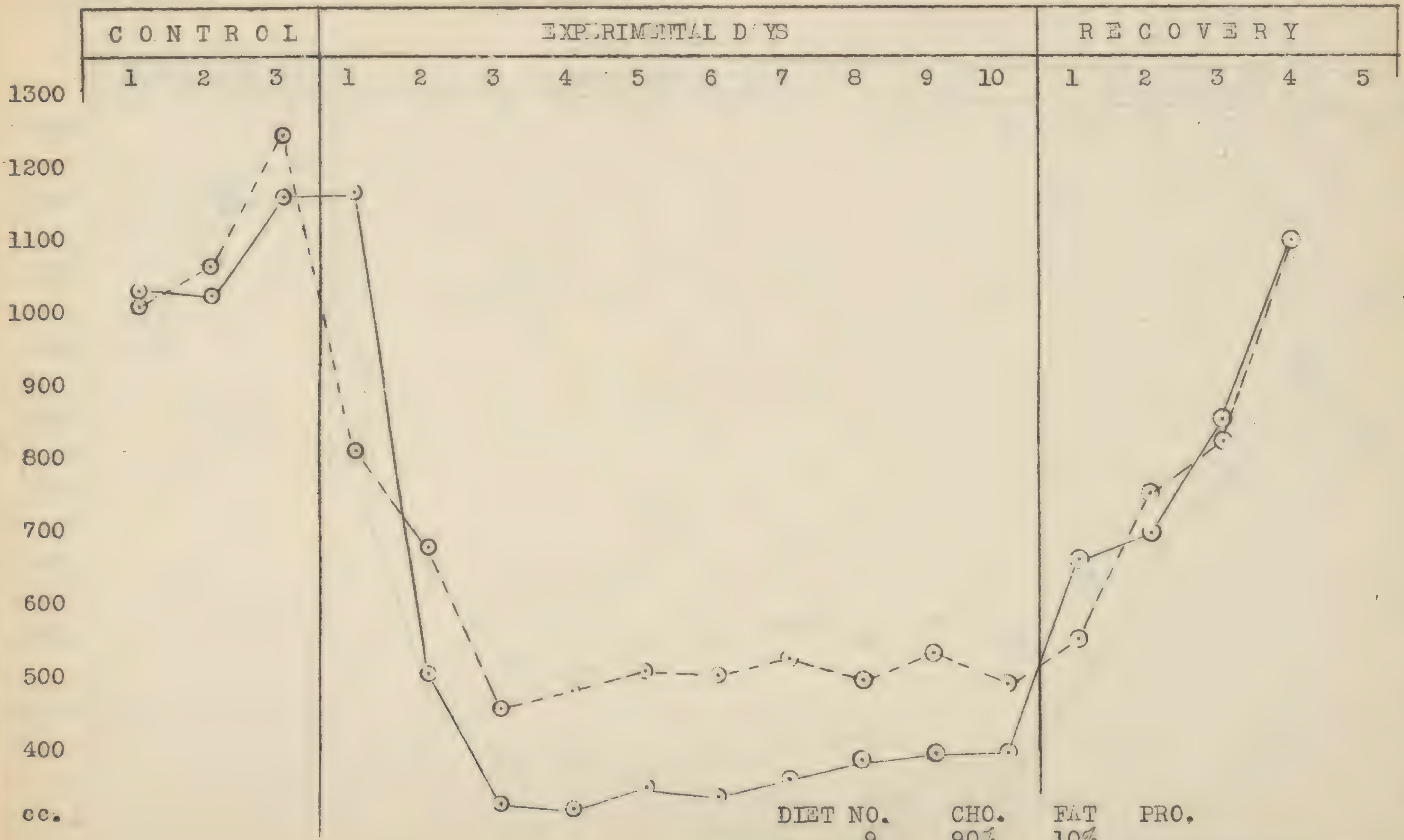
DAILY WEIGHT LOSS
(Kilograms)



DIET NO.	CHO.	FAT	PRO. (Milk)
9	90%	10%	
10	80%	10%	10%

FIGURE 11

TOTAL URINARY VOLUME
(cc.)

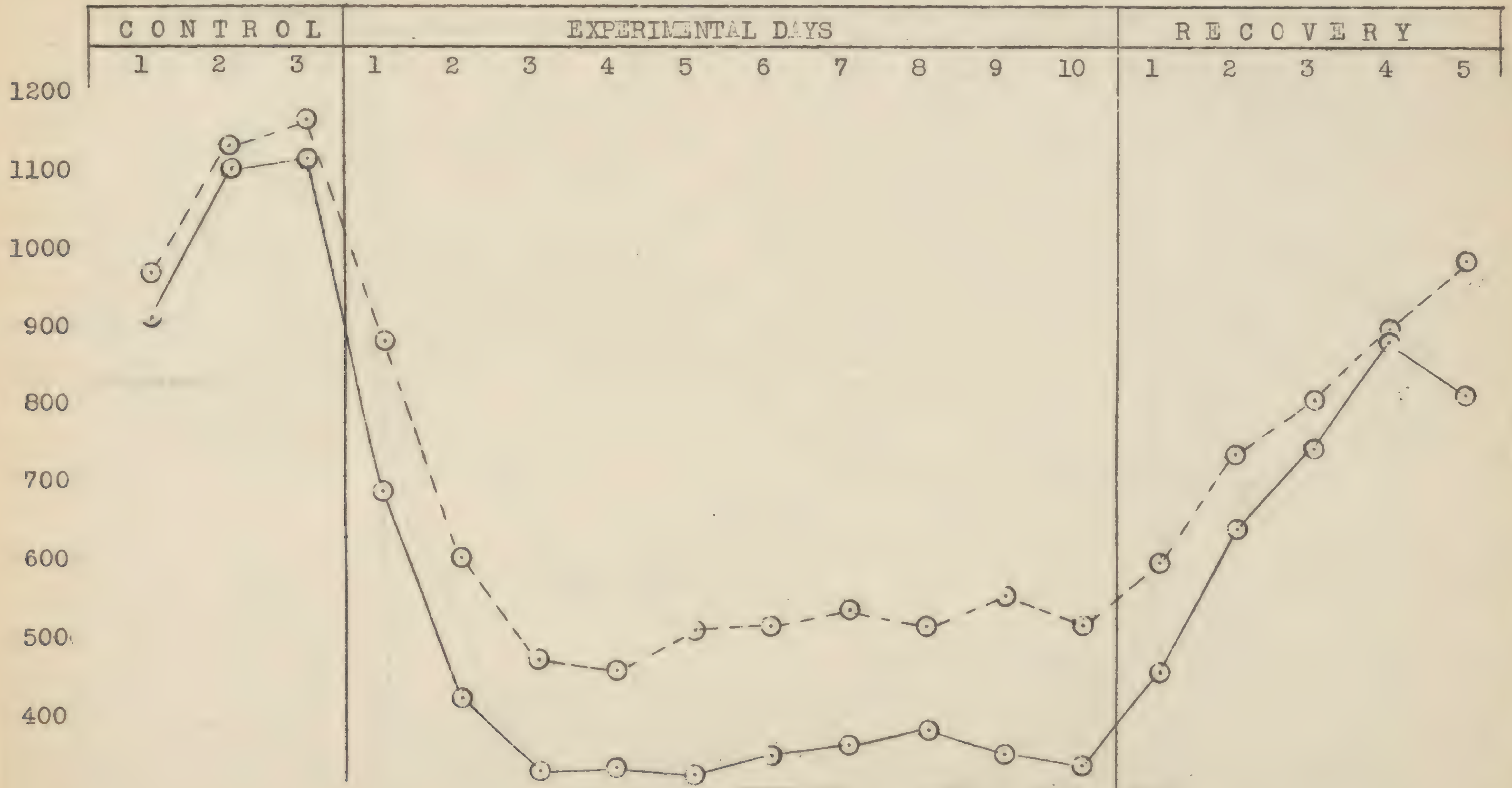


DIET NO.	CHO.	FAT	PRO.
——— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

(continued)

TOTAL MILLIOSMOLS IN URINE

FIGURE 11A



DIET NO.	CHO.	FAT	PRO.
—— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

(continued)

RESTRICTED

FIGURE 12

TOTAL NITROGEN IN URINE

(Grams)

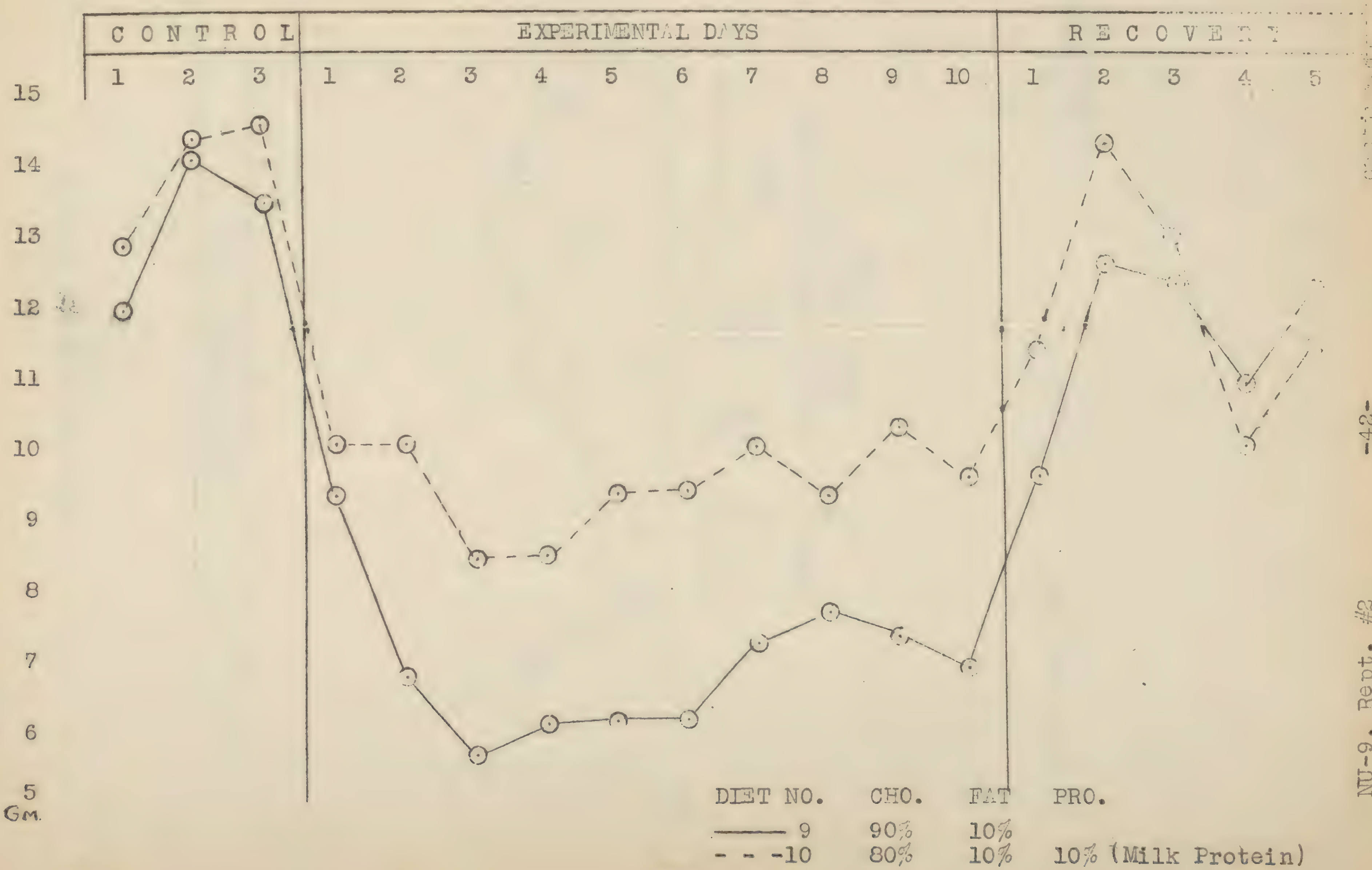
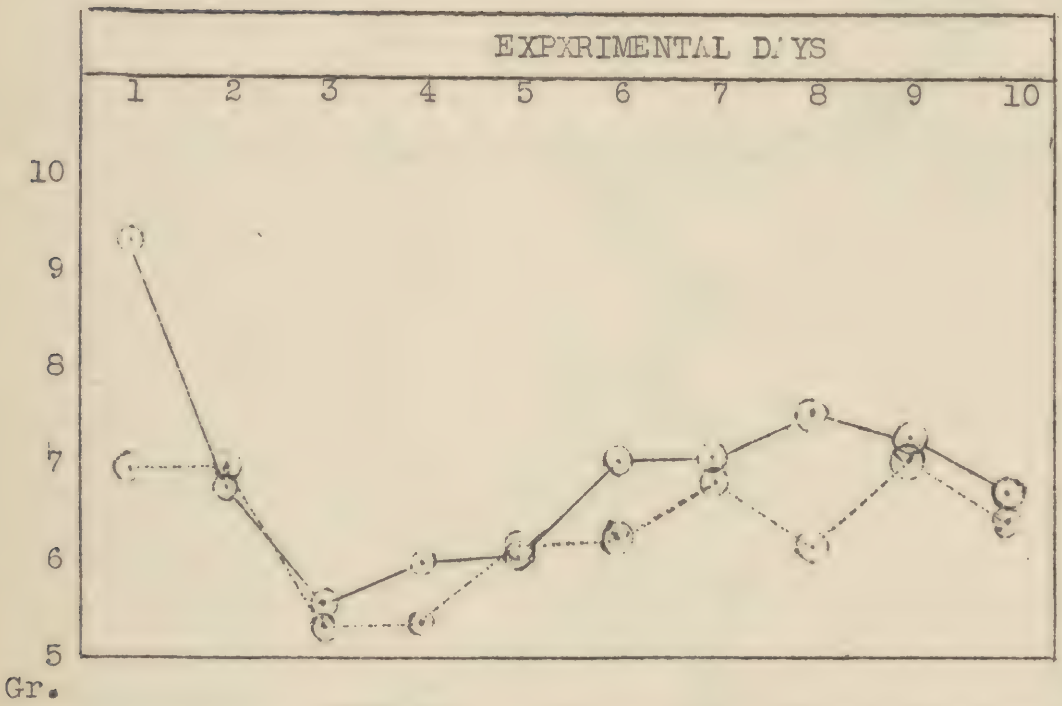


FIGURE 12A

NEGATIVE NITROGEN BALANCE
(Grams)

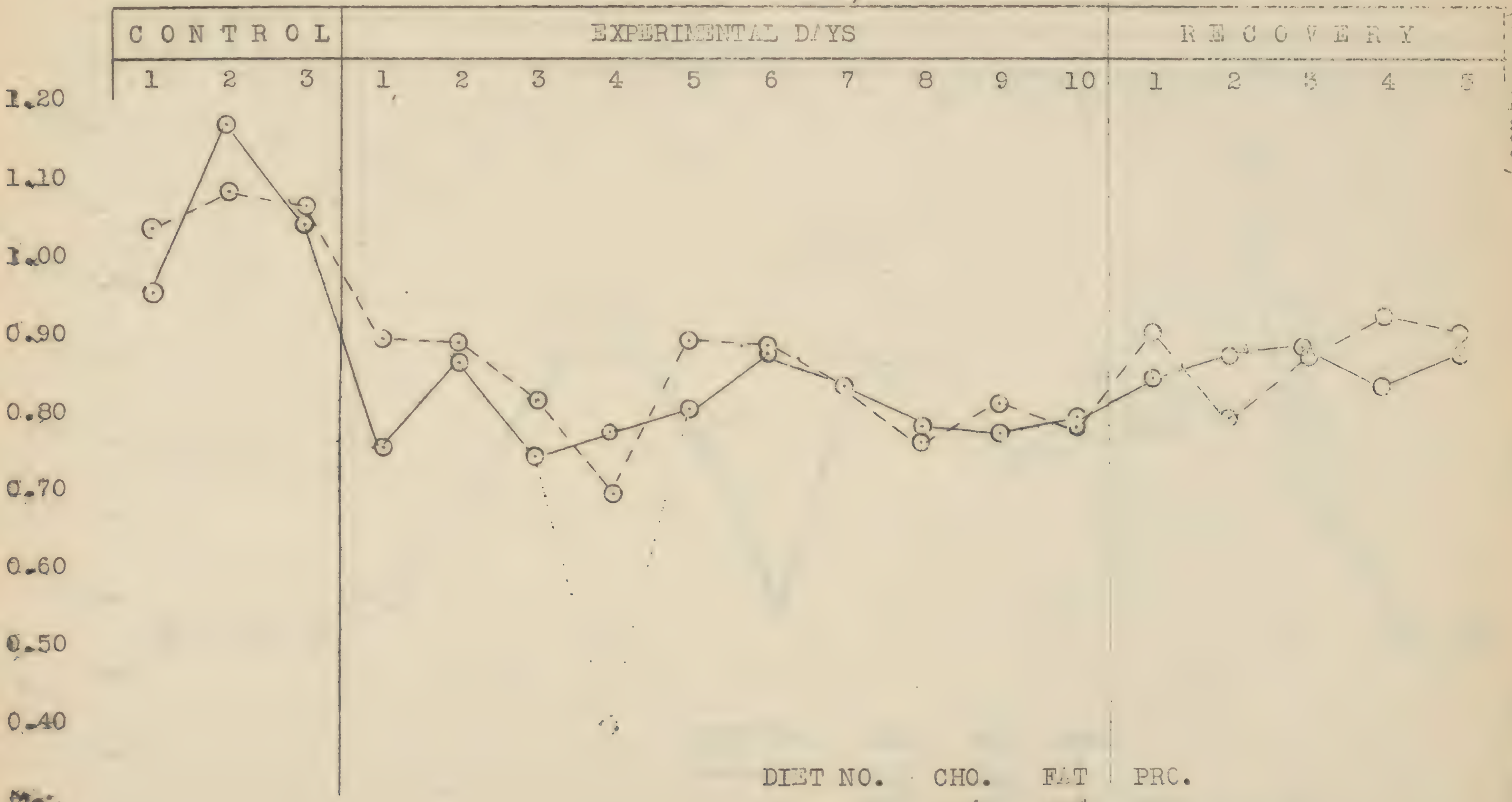


DIET NO.	CHO.	FAT	PRO. (Milk Pro.)
—— 9	90%	10%	
-----10	80%	10%	10%

DIET NO.	AVERAGE DAILY N_2 BALANCE
9	Minus 6.8
10	Minus 6.35

FIGURE 13

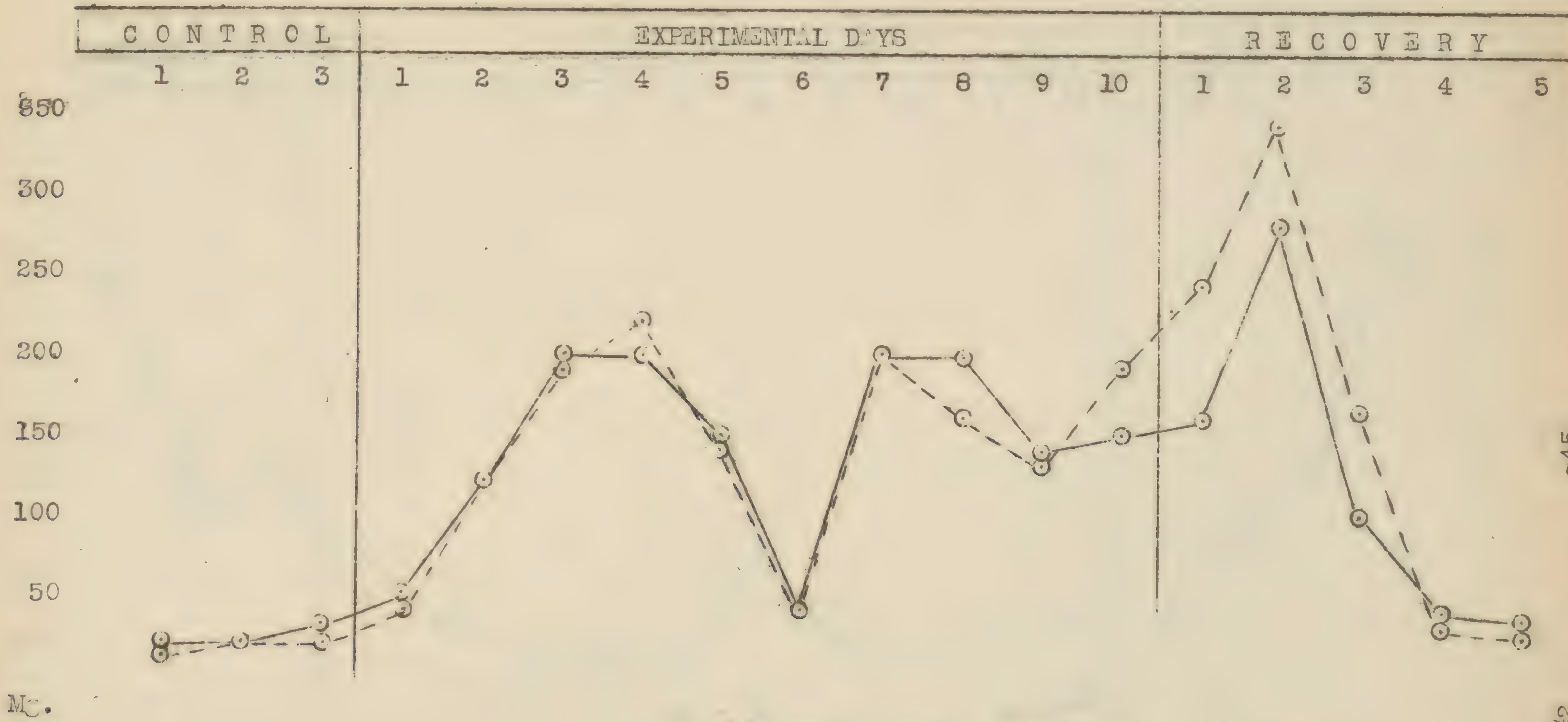
TOTAL CREATININE IN URINE
(Milligrams)



DIET NO.	CHO.	FAT	PRC.
——— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

FIGURE 14

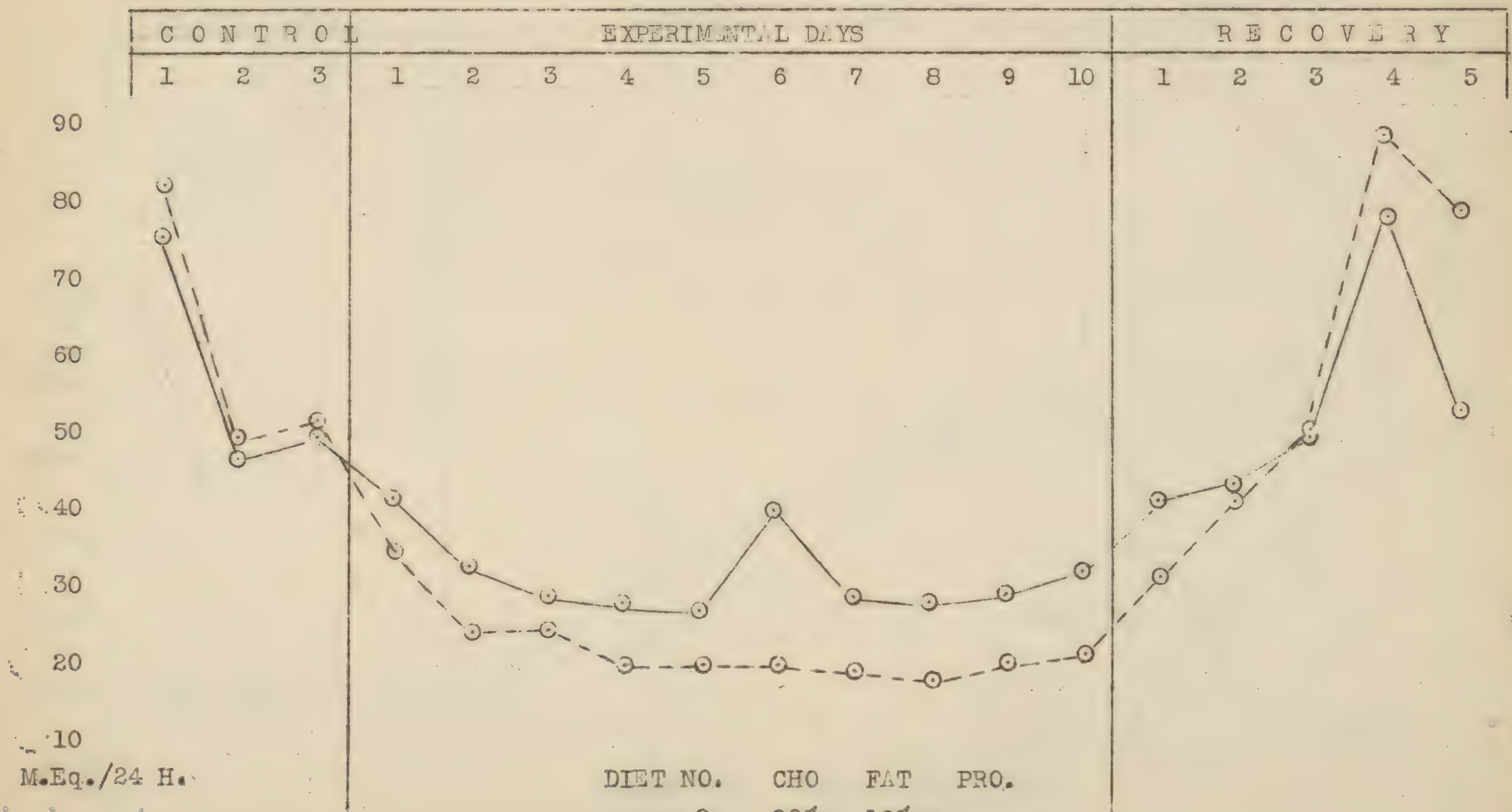
TOTAL CREATINE IN URINE
(MILLIGRAMS)



DIET NO.	CHO.	FAT	PRO.
——— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

FIGURE 15

TOTAL NH_3 NITROGEN IN URINE
(Milliequivalents per 24 Hour)



DIET NO.	CHO	FAT	PRO.
—— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

(continued)

FIGURE 16

BLOOD NON-PROTEIN NITROGEN
(Milligrams per 100 cc)

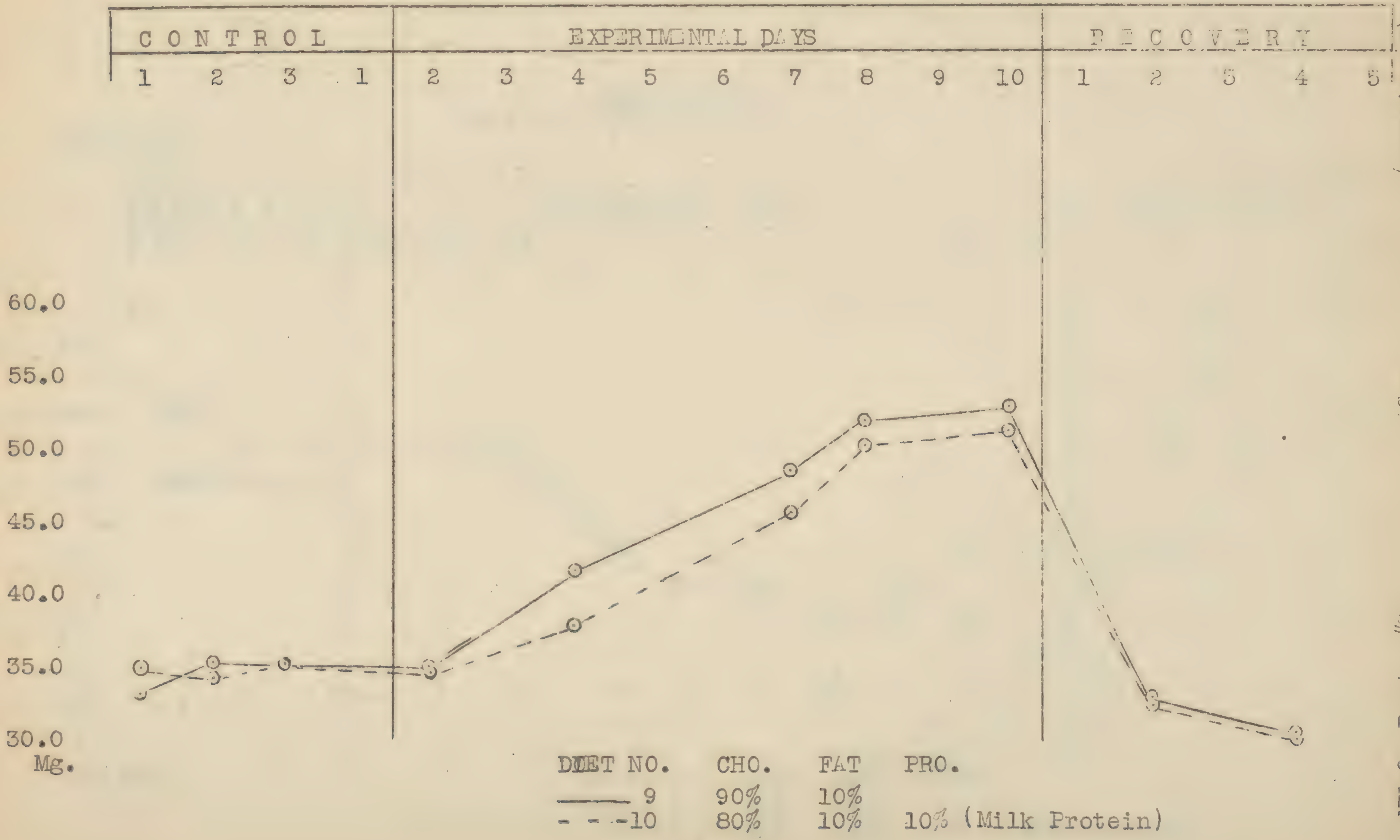
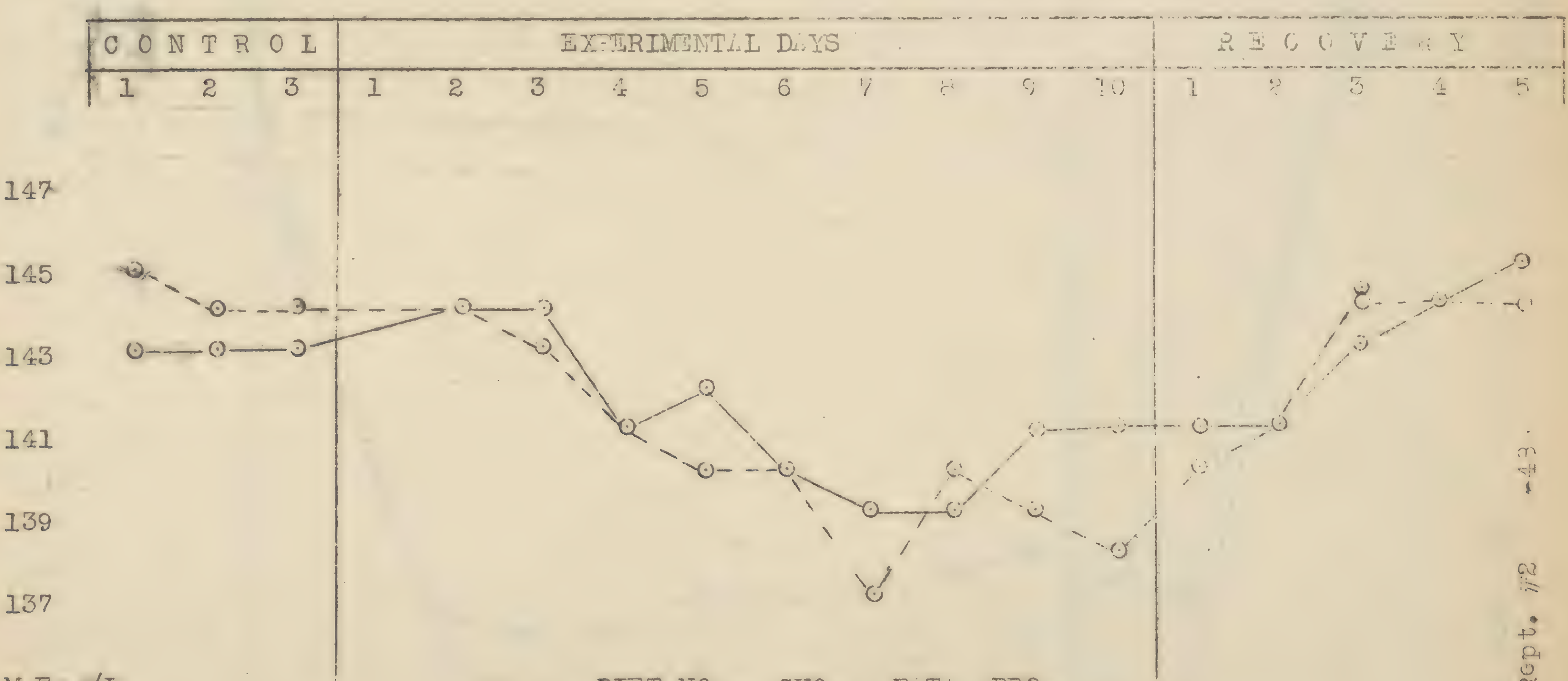


FIGURE 17

SERUM SODIUM
(Milliequivalents Per Liter)

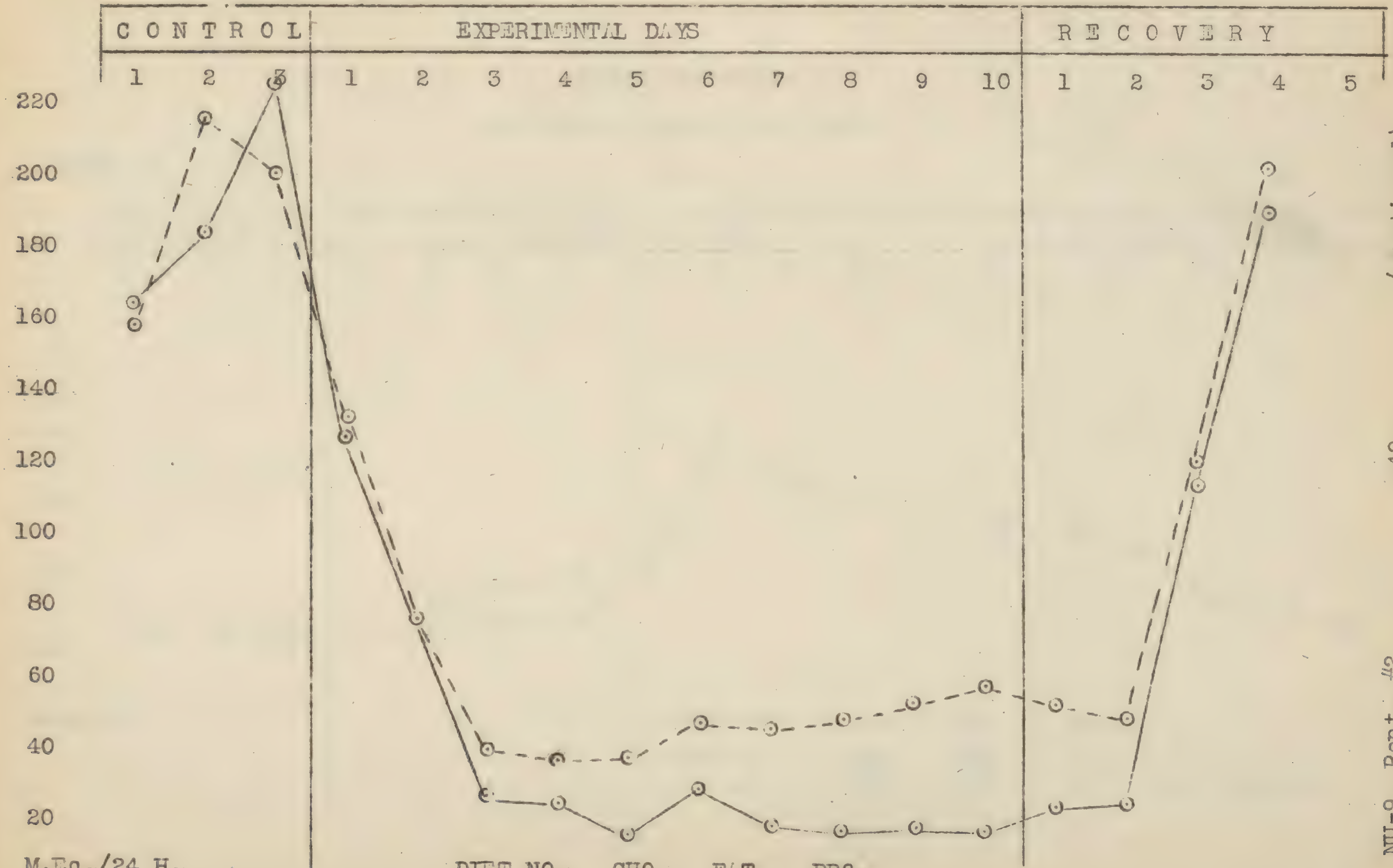


DIET NO.	CHO.	FAT	PRO.
——— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

(continued)
RESTRICTED

FIGURE 17A

TOTAL SODIUM IN URINE
(Milliequivalents Per 24 Hours)

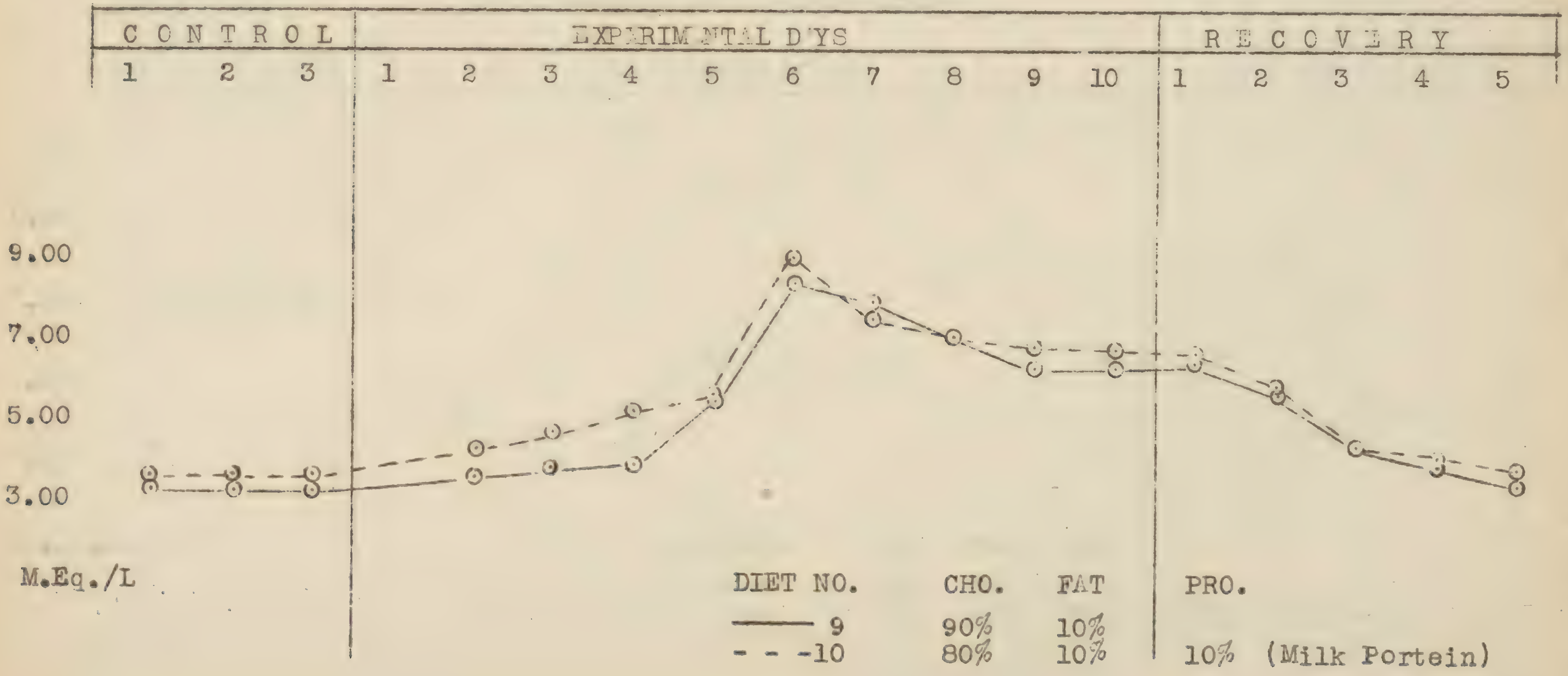


DIET NO.	CHO.	FAT	PRO.
——— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

FIGURE 18

SERUM POTASSIUM

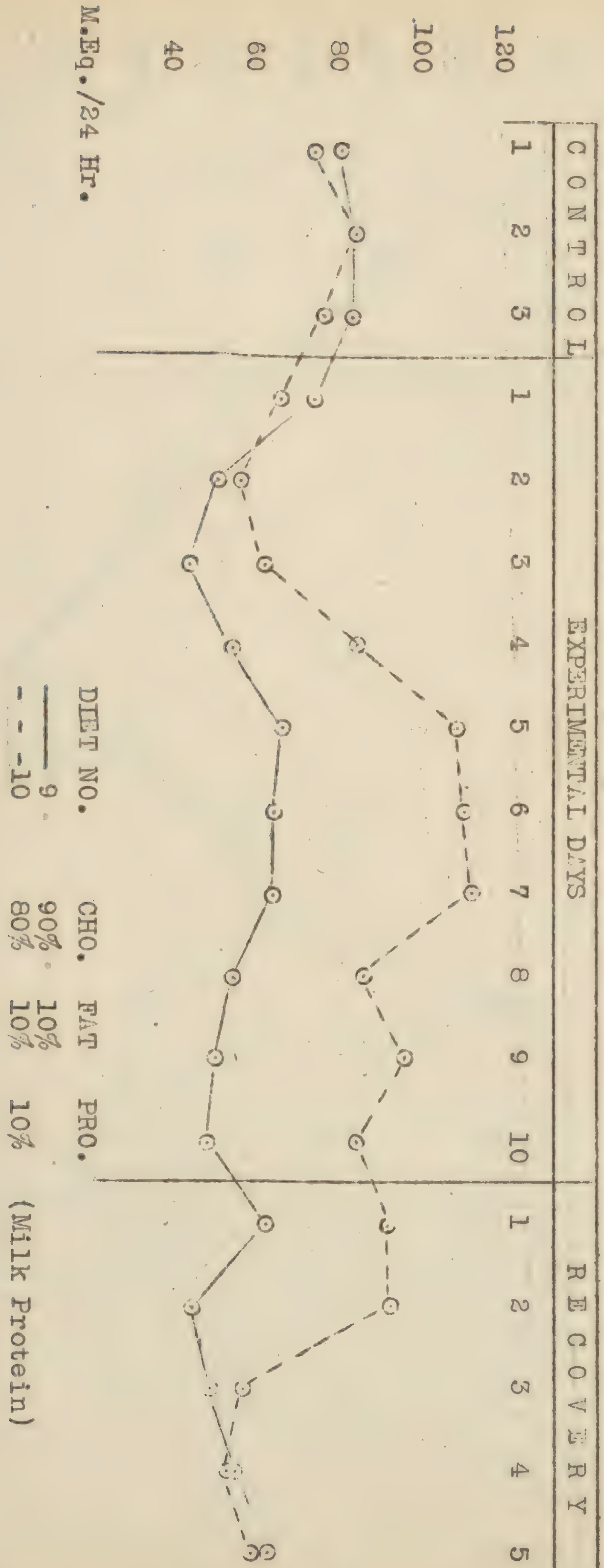
(Milliequivalents Per Liter)



(continued)

FIGURE 18A

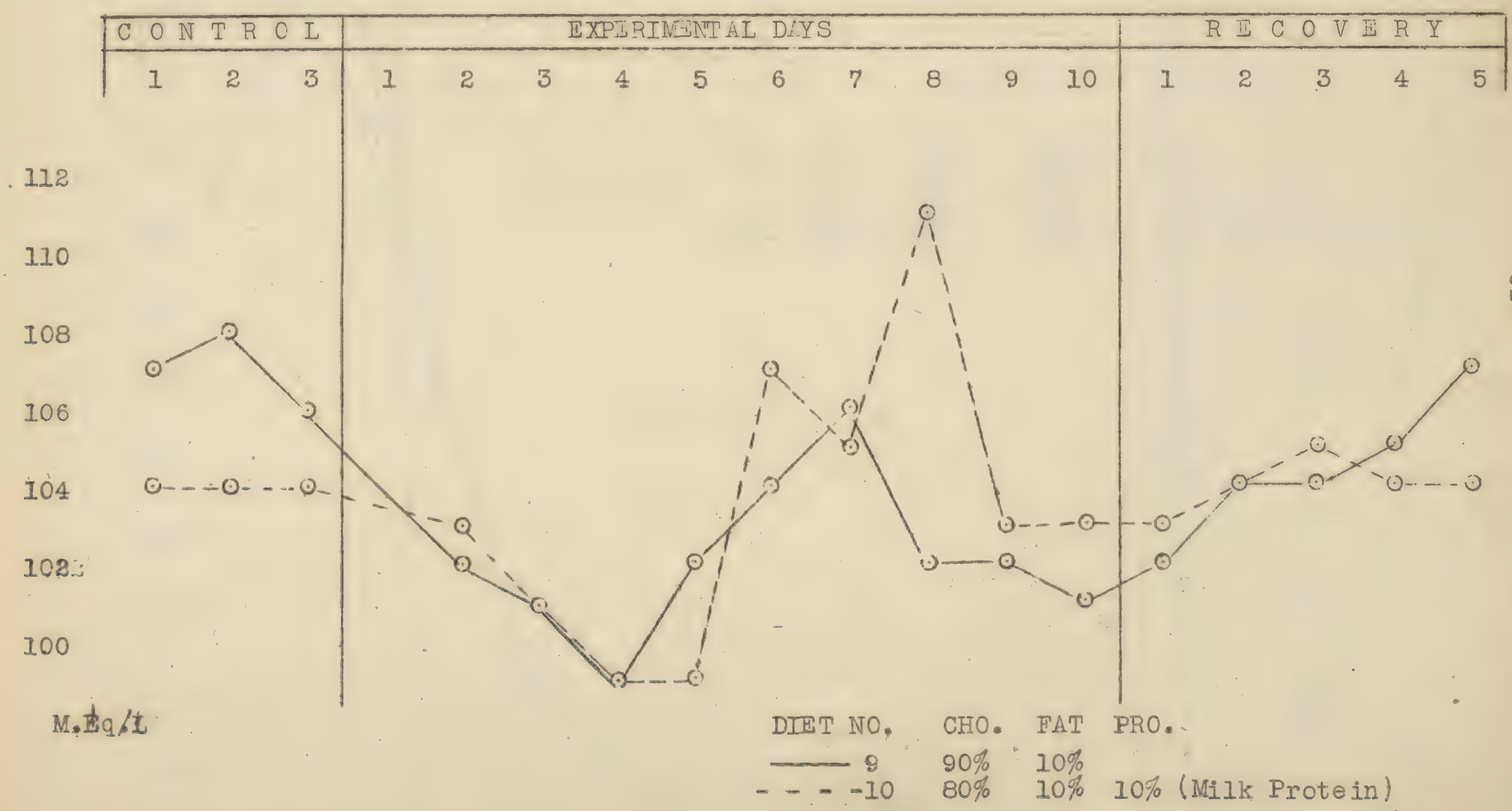
POTASSIUM IN URINE
(Milliequivalents Per 24 Hours)



(continued)

FIGURE 19

SERUM CHLORIDES
(Milliequivalents Per Liter)



(continued)
RESTRICTED

TOTAL CHLORIDES IN URINE
(Milliequivalents Per 24 Hours)

FIGURE 19A

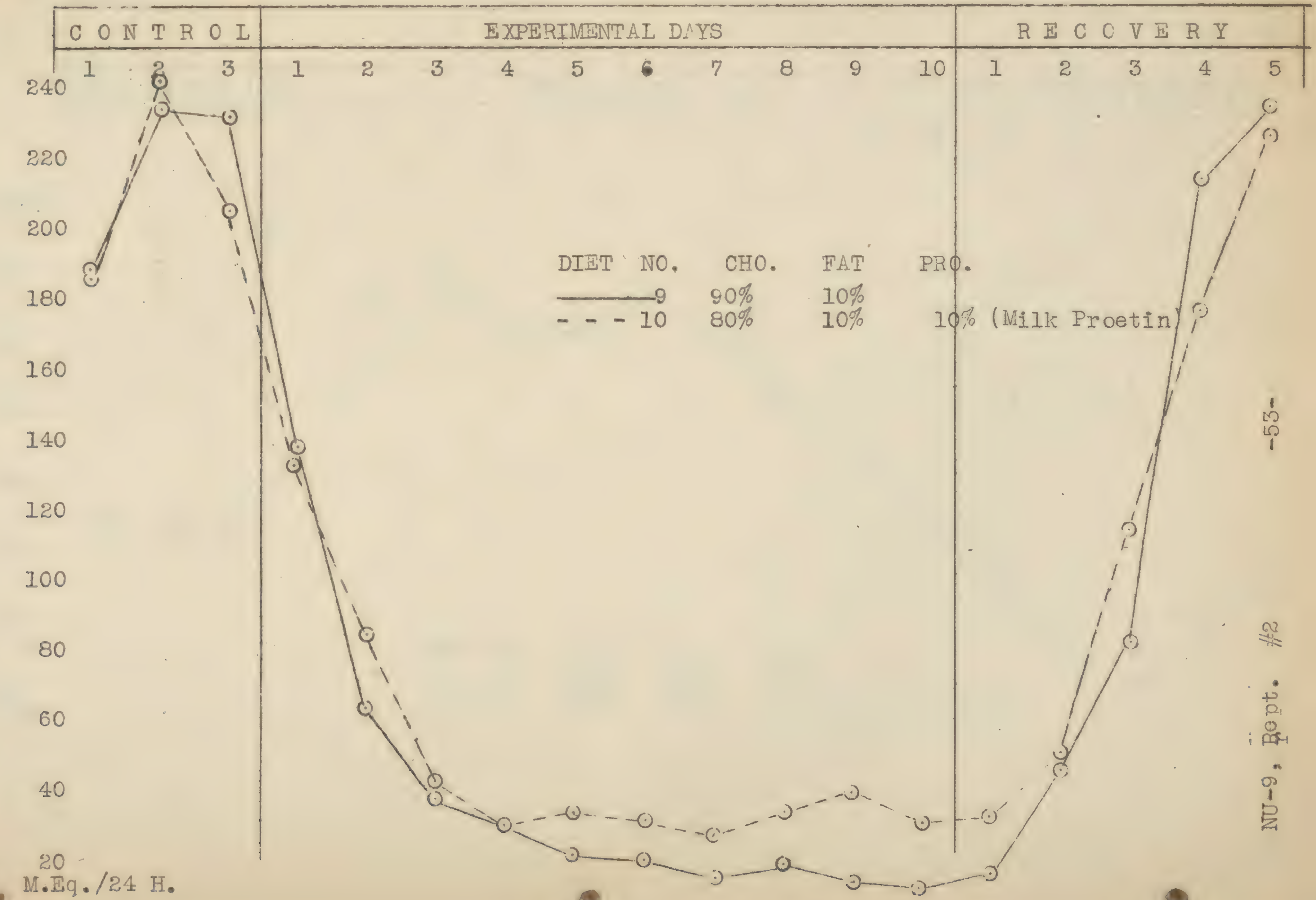


FIGURE 21

TOTAL SERUM CHOLESTEROL
(Milligrams per 100 cc.)

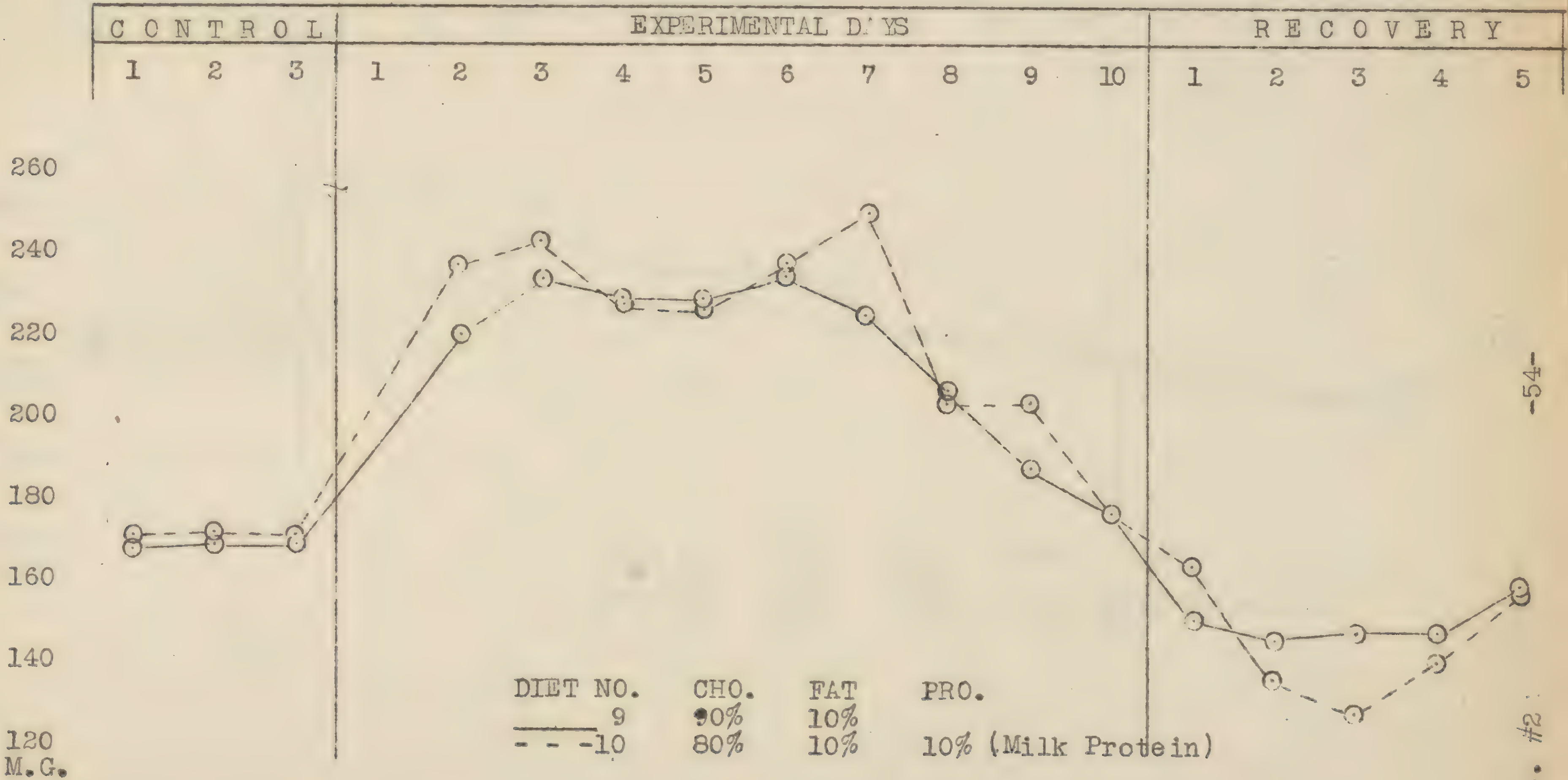
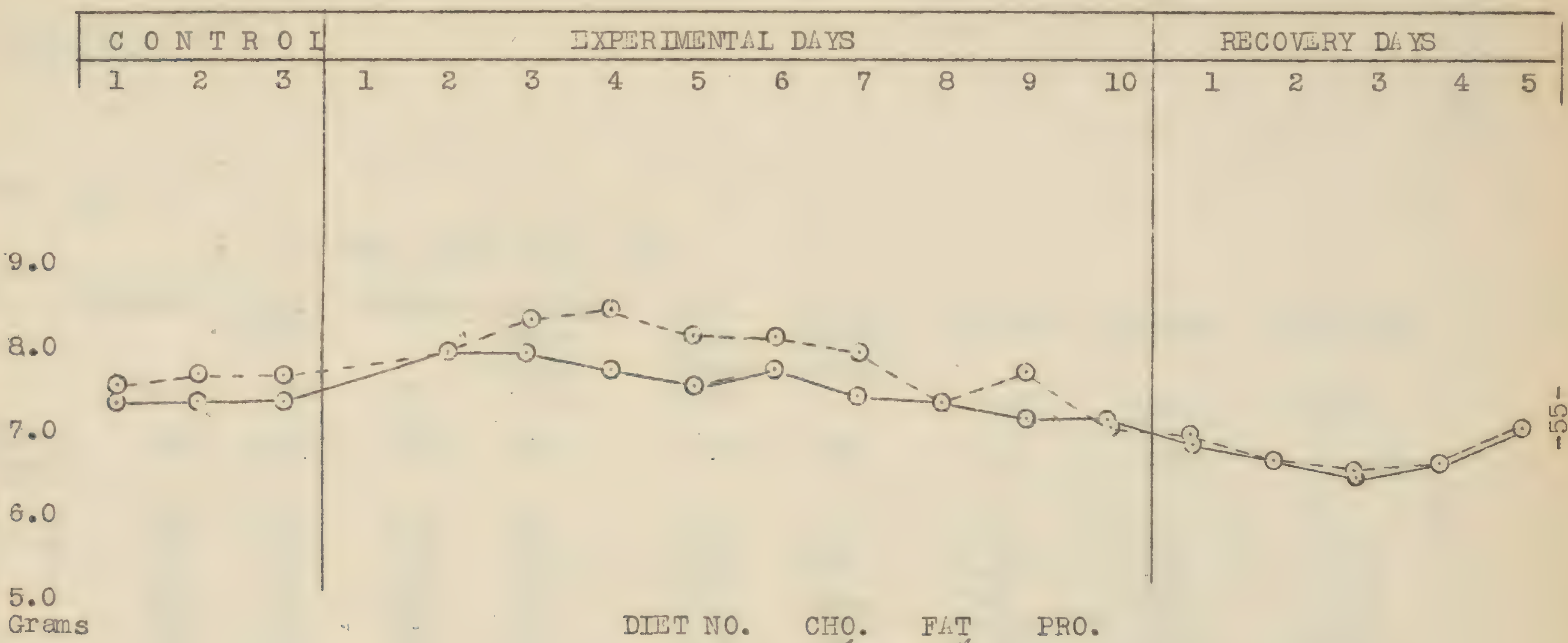


FIGURE 22

TOTAL SERUM PROTEINS
(Grams per 100 cc.)



DIET NO.	CHO.	FAT	PRO.
——— 9	90%	10%	
- - -10	80%	10%	10% (Milk Protein)

(continue
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WELFARE ISLAND, NEW YORK CITY

(continued)
RESTRICTED

GROUP AVER. DIET 11
CHO 10%
FAT 10%

TABLE 8A

24 HOUR URINE COLLECTION

Day	Weight (kg)	Water Intake (cc)	Volume (cc)	Minimal Urine Volume (cc)	Depr. Fr.P. degree cent.	Total Milli-osmols	Sodium (gm)	Potass (gm)	Chlorides (gm)
Control Aver.	71.4	2316	1287	703	1.45	987	4.54	3.65	12.4[illegible]
Deprivation 1	70.3	800	1226	455	0.98	637	2.41	3.56	6.94
2	69.4	800	722	300	1.08	419	1.31	3.08	3.74
3	69.0	800	472	247	1.41	345	0.66	3.05	2.16
4	68.5	800	416	180	1.31	280	0.61	2.58	1.57
5	68.5	800	412	214	1.42	297	0.28	1.21	0.99
6	68.0	800	534	215	1.10	298	0.29	0.89	0.87
7	67.7	800	387	184	1.29	258	0.27	1.02	0.86
8	67.5	800	394	179	1.23	250	0.34	1.06	0.74
9	67.1	800	366	172	1.29	240	0.33	1.06	0.69
10	66.9	800	329	167	1.37	234	0.24	0.97	0.74
Recovery 1	67.2	2196	1275	250	0.54	266	0.42	0.93	0.57
2	68.6	2034	668	365	1.53	510	1.34	1.63	2.82
3	69.2	2096	1154	506	1.38	708	3.63	1.96	8.56
4	69.8	1988	1032	635	1.69	855	4.27	1.76	11.54
5	69.6	1752	978	681	1.59	952	5.95	2.64	13.60

GROUP AVER. DIET IL
CHO 90%
FAT L10%

TABLE 8B

24 HOUR URINE COLLECTION

Day	Total Nitrogen (gm)	Urea Nitrogen (gm)	NH_3 Nitrogen (gm)	Creatine (gm)	Creatinine (gm)
Control Aver.	12.09	9.87	0.71	0.01	1.05
Deprivation 1	8.03	5.97	0.97	0.01	1.03
2	5.91	4.66	0.46	0.02	1.02
3	5.50	4.38	0.45	0.01	0.94
4	5.28	4.18	0.37	0.19	0.81
5	5.31	4.04	0.36	0.05	0.84
6	5.26	4.38	0.36	0.12	0.97
7	4.46	3.39	0.33	0.08	0.80
8	4.41	3.33	0.30	0.08	0.75
9	4.27	3.20	0.35	0.02	0.89
10	4.21	3.13	0.39	0.08	0.84
Recovery 1	6.70	5.80	0.52	0.08	1.12
2	8.42	6.81	0.52	0.03	1.14
3	9.02	7.54	0.57	0.09	1.05
4	10.42	8.37	0.77	0.08	0.75
5	10.89	8.96	0.70	0.03	0.68

(continued)

NEW YORK MEDICAL COLLEGE, METROPOLITAN HOSPITAL RESEARCH UNIT
WELFARE ISLAND, NEW YORK CITY

GROUP AVER. - DIET 12
CHO 80%
FAT 10%
PROT 10% (Egg white)

TABLE 8C

24 HOUR URINE COLLECTION

Day	Weight (kg)	Water Intake (cc)	Volume (cc)	Minimal Urine Volume (cc)	Depr. Fr.P. degree cent.	Total Milli-osmols	Sodium (gm)	Potass (gm)	Chlorides (gm)
Control Aver.	72.0	2577	1425	664	1.42	971	4.46	2.87	12.28
Deprivation 1	70.7	800	1268	475	1.00	664	2.68	3.33	7.18
2	69.9	800	723	354	1.33	495	1.76	3.16	4.18
3	69.6	800	591	313	1.52	438	0.98	3.28	2.66
4	68.8	800	433	217	1.39	503	0.53	2.74	1.88
5	68.5	800	466	264	1.65	370	0.36	1.45	1.12
6	68.2	800	473	254	1.61	355	0.42	1.39	1.04
7	68.0	800	373	239	1.72	335	0.33	1.37	0.84
8	67.6	800	420	240	1.64	335	0.40	1.34	0.73
9	67.4	800	380	221	1.64	309	0.39	1.22	0.72
10	67.2	800	335	207	1.67	289	0.35	1.43	0.84
Recovery 1	67.7	2234	987	302	0.89	423	0.54	1.04	0.62
2	6[illegible].6	2464	674	404	1.67	565	1.53	1.03	2.46
3	69.[illegible]	2148	1129	581	1.45	812	4.22	2.42	10.49
4	70.[illegible]	2064	1236	619	1.48	865	4.58	1.97	12.12
5	7[illegible].0	1998	1009	667	1.79	934	5.94	2.16	11.55

(continued)

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WELFARE ISLAND, NEW YORK CITY

GROUP AVER. - DIET 12
CHO 80%
FAT 10%
PROT 10% (Egg white)

TABLE 8D

24 HOUR URINE COLLECTION

Day		Total Nitrogen (gm)	Urea Nitrogen (gm)	NH_3 Nitrogen (gm)	Creatine (gm)	Creatinine (gm)
Control Aver.		11.62	9.27	0.72	0.01	0.96
Deprivation	1	8.48	6.61	0.57	0.00	1.01
	2	7.34	6.15	0.46	0.01	1.01
	3	7.36	6.24	0.47	0.01	0.98
	4	6.85	5.42	0.40	0.16	0.80
	5	6.89	5.69	0.40	0.07	0.84
	6	6.70	5.49	0.38	0.14	0.89
	7	6.38	5.02	0.34	0.12	0.79
	8	6.44	5.22	0.37	0.03	0.72
	9	6.03	4.83	0.37	0.09	0.78
	10	5.77	4.64	0.40	0.11	0.87
Recovery	1	7.97	6.76	0.53	[illegible]	1.12
	2	8.58	6.96	0.52	0.06	1.04
	3	9.20	7.41	0.74	0.06	1.17
	4	9.67	7.63	0.84	0.08	0.71
	5	10.77	8.70	0.70	0.03	0.68

(continued)
RESTRICTED

(continued)
RESTRICTED

GROUP AVER. DIET 11
CHO 90%
FAT 10%

Table 9A

FASTING BLOOD

Day	Sodium	Potassium	Chlorides	Sugar	NPN	UN	Total Chol.
Control Aver.	332 332	15.9	608	78.8	31.2	15.2	179
Deprivation 1	328	16.9	582				229
2	328	21.8	612	78.4	32.6	15.9	21[illegible]
3	327	21.0	577				207
4	317	19.5	582	82.0	33.9	16.5	214
5	326	29.6	602				232
6	326	20.8	590	80.6	32.3	16.3	195
7	322	20.6	591				198
8	321	20.1	601	80.5	32.9	16.3	186
9	322	22.0	302				168
10	313	19.4	582	89.6	35.4	17.9	200
Recovery 1	328	15.8	602				183
2	340	20,6	606				191
3	335	16.7	604	80.2	30.5	15.5	156
4	326	14.2	582				152
5	334	14.9	601	83.9	29.2	14.6	177

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WELFARE ISLAND, NEW YORK CITY

GROUP AVER. DIET 11
CHO 90%
FAT 10%

TABLE 9B

FASTING BLOOD

Day	TSP	ALB	GLOB	A/G	Hemat	RBC	HGB
Control Aver.	7.6	6.8	1.5	4.4	40	4.50	15.1
Deprivation 1	8.3	7.0	1.3	6.9	41	4.40	14.9
2	8.2	6.3	1.9	3.6	38	4.19	14.3
3	8.2	6.2	2.0	3.1	41	4.27	14.2
4	7.0	5.2	1.8	3.0	36	4.29	14.7
5	7.7	5.4	2.3	2.3			
6	7.8	5.5	2.3	2.5	39	4.15	14.4
7	7.7	6.3	1.6	4.1	38	3.92	13.5
8	7.6	6.4	1.3	6.9	38	3.64	13.2
9	7.9	5.0	2.9	1.8	40	3.76	13.3
10	8.1	6.1	1.9	3.2	38	4.01	14.0
Recovery 1	7.3	5.2	2.1	2.5	37	3.79	13.3
2	7.5	5.6	1.8	3.2	37		
3	7.9	5.3	2.5	2.2	39	4.33	14.5
4	7.4	5.5	1.9	3.3	37	4.22	14.4
5	8.3	6.5	1.8	3.9	42		

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WELFARE ISLAND, NEW YORK CITY

GROUP AVER. DIET 12
CHO 80%
Fat 10%
PROT 10% (Egg white)

TABLE 9C

FASTING BLOOD

Day	Sodium	Potassium	Chlorides	Sugar	NPN	UN	Total chol.
Control Aver.	332	17.3	605	77.1	30.3	14.9	199
Deprivation 1	328	18.1	574				240
2	330	22.2	607	75.4	31.9	15.7	222
3	327	21.6	580				215
4	321	21.4	595	85.5	33.4	16.3	240
5	321	30.9	594				242
6	323	24.6	589	79.9	31.9	16.1	219
7	325	23.9	582				216
8	327	21.5	580	82.5	32.7	16.0	191
9	324	21.1	610				173
110	319	21.8	583	85.7	35.9	17.2	206
Recovery 1	334	16.5	582				195
2	332	19.3	625				195
3	322	15.3	626	77.4	30.0	15.3	171
4	324	12.8	610				167
5	330	14.8	606	81.7	27.7	14.2	171

NEW YORK MEDICAL COLLEGE, METROPOLITAN HOSPITAL RESEARCH UNIT
WELFARE ISLAND, NEW YORK CITY

GROUP AVER. DIET 12
CHO 80%
FAT 10%
PROT 10% (Egg white)

TABLE 9D

FASTING BLOOD

Day		TSRiu	ALB	GLOB	A/G	Hemat	RBC	HGB
Control Aver.		8.0	6.0	2.0	3.4	42	4.51	15.3
Deprivation	1	8.1	7.0	1.1	6.0	42	4.18	15.1
	2	8.4	666	1.8	3.7	40	4.00	13.6
	3	8.1	7.7	1.9	3.8	42	4.10	14.0
	4	7.3	5.0	2.4	2.3	39	4.03	14.3
	5	8.0	5.6	2.3	2.5			
	6	8.3	5.6	2.7	2.1	41	4.06	13.8
	7	8.1	6.0	2.0	3.6	39	4.01	13.7
	8	8.0	5.6	2.5	2.3	40	3.89	13.4
	9	7.8	5.9	2.9	1.9	37	3.85	13.3
	10	8.0	6.0	2.0	3.4	38	3.99	13.1
Recovery	1	7.5	5.4	2.1	2.9	38	3.98	13.0
	2	7.3	5.3	2.[illegible]	2.9	39		
	3	7.6	5.3	2.3	2.5	43	4.47	14.0
	4	7.4	5.6	1.8	3.1	39	4.46	14.1
	5	8.3	6.4	2.0	3.4	42		

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WELFARE ISLAND, NEW YORK CITY

GROUP AVER. DIET 11
CHO 90%
FAT 10%

TABLE 10A

TOTAL MILLI-EQUIVALENTS

Day	Sodium Urine	Sodium Blood	Potassium Urine	Potassium Blood	Chlorides Urine	Chlorides Blood	NH_3 Nitrogen Urine
Control Aver.	197	145	94	3.47	214	105	51
Deprivation 1	105	143	91	4.34	120	100	69
2	57	143	79	5.59	65	105	33
3	29	142	78	5.39	37	100	32
4	27	138	66	5.00	27	100	26
5	12	142	31	7759	17	104	26
6	13	142	23	5.34	15	100	26
7	12	140	26	5228	15	100	24
8	15	140	27	5.16	13	100	21
9	14	140	27	5.64	12	100	25
10	10	136	25	4.98	13	100	28
Recovery 1	18	143	24	4.05	10	104	37
2	58	148	42	5.29	49	104	37
3	158	146	50	4.28	148	104	41
4	186	142	45	3.64	199	100	55
5	259	145	68	3.82	235	103	50

(continued)

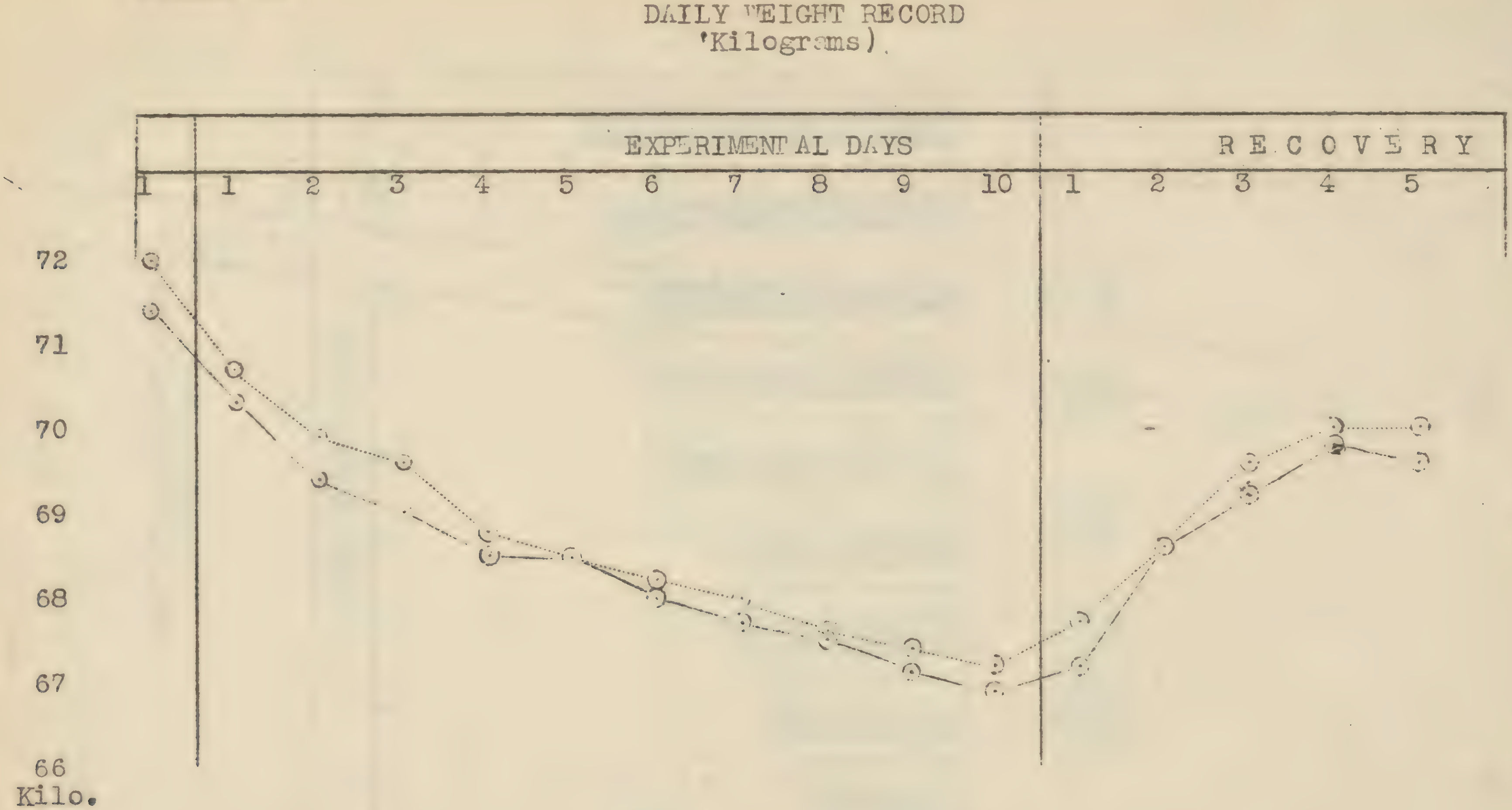
GROUP AVER. DIET 12
CHO 80%
FAT 10%
PROT 10% (Egg white)

Table 10B

TOTAL MILLI-EQUIVALENTS

Day	Sodium Urine	Sodium Blood	Potassium Urine	Potassium Blood	Chlorides Urine	Chlorides Blood	NH_3 Nitrogen Urine
Control Aver.	194	145	73	3.83	212	104	52
Deprivation 1	117	143	85	4.64	124	99	41
2	77	144	81	5.69	72	104	33
3	43	142	84	5.54	46	100	33
4	23	140	70	5.49	32	102	29
5	16	140	37	7.92	19	102	29
6	18	140	36	6.30	18	101	27
7	14	141	35	6.13	14	100	24
8	17	142	35	5.51	13	100	26
9	17	141	31	5.42	12	105	26
10	15	139	37	5.60	14	102	29
Recovery 1	24	145	27	4.24	11	100	38
2	67	144	26	4.95	42	108	37
3	180	140	62	3.93	181	108	53
4	199	141	50	3.29	209	105	60
5	258	144	55	3.80	199	104	50

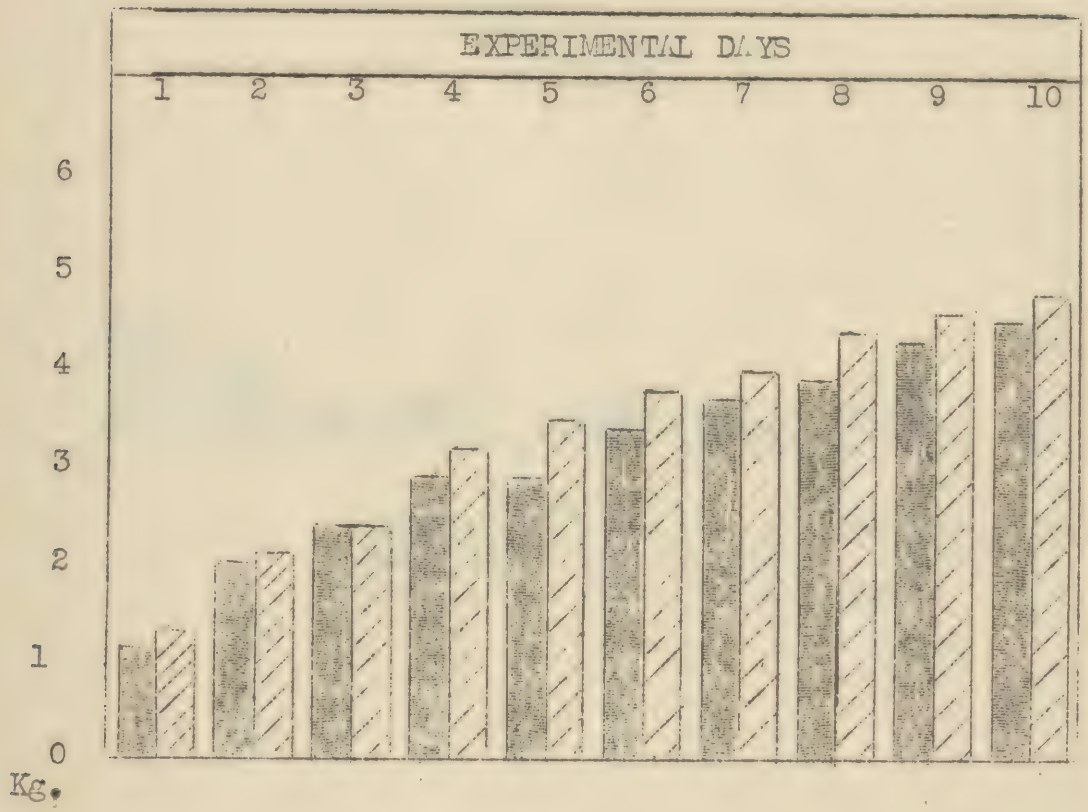
FIGURE 23



DIET NO.	CHO.	FAT	EGG WHITE
—— 11	90%	10%	
······ 12	80%	10%	10%

FIGURE 23A

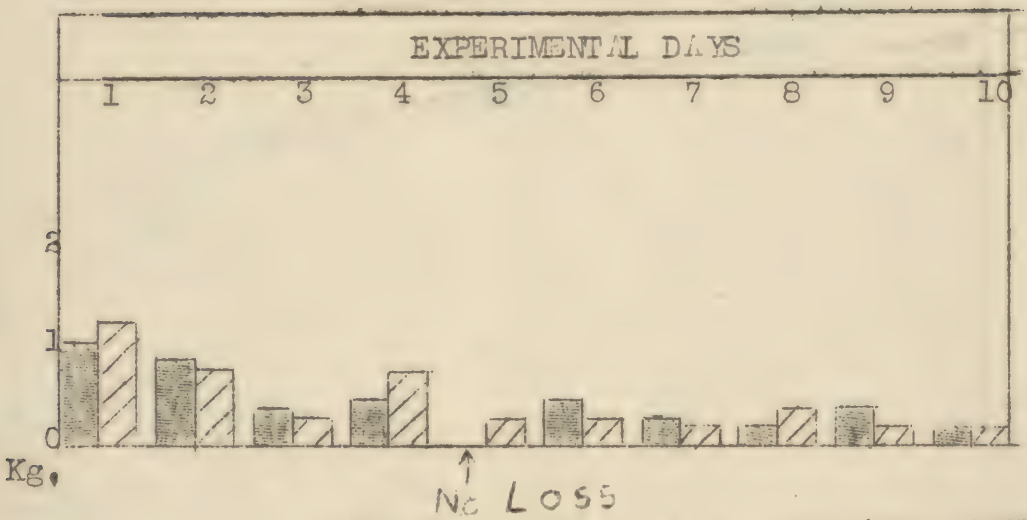
CUMULATIVE WEIGHT LOSS
(Kilograms)



DIET NO.	CHO.	FAT	PRO. (EGG WHITE)
11	90%	10%	
12	80%	10%	10%

FIGURE 23B

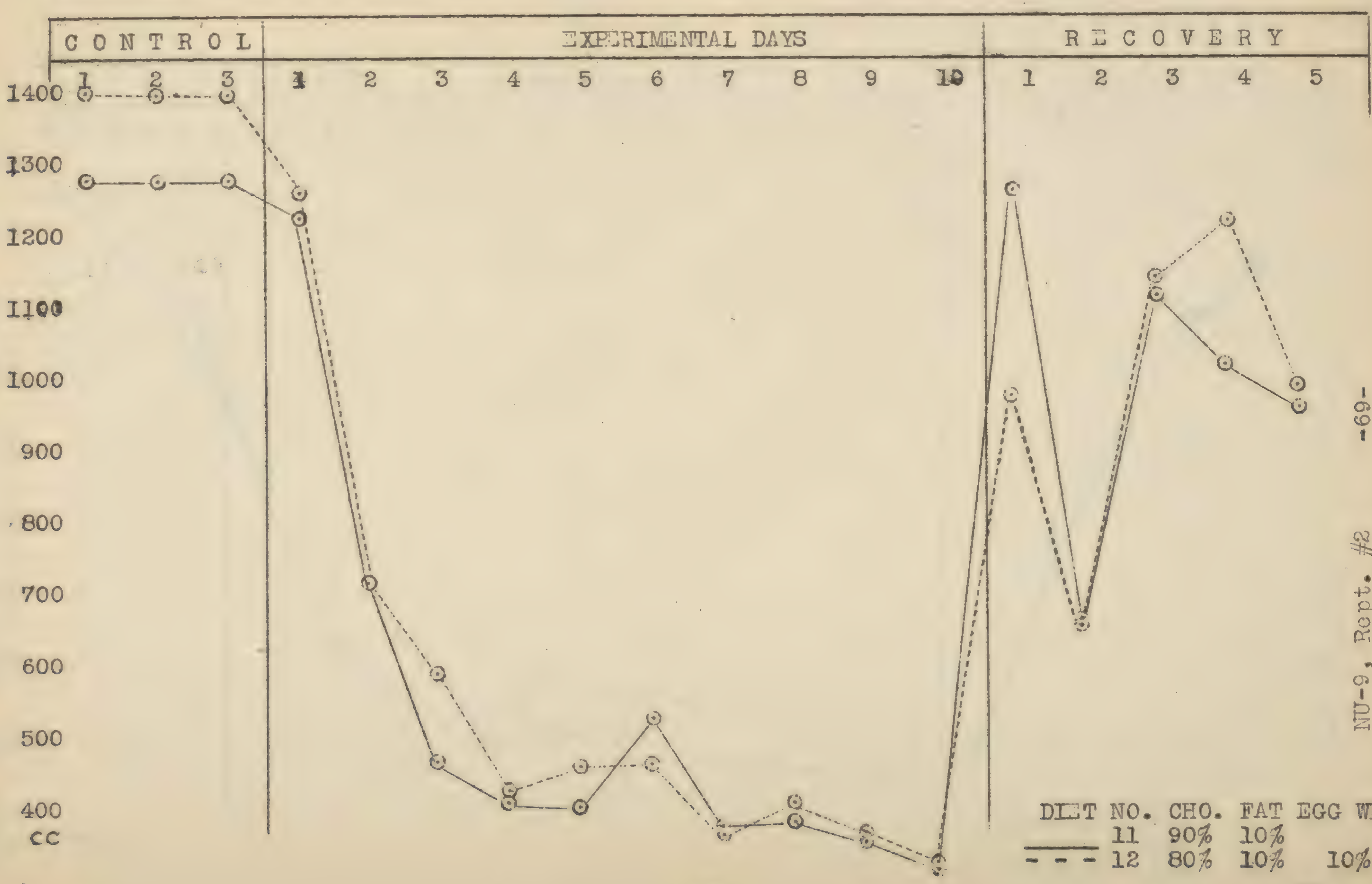
DAILY WEIGHT LOSS
(Kilograms)



DIET NO.	CHO.	FAT	PRO.(EGG WHITE)
11	90%	10%	
12	80%	10%	10%

FIGURE 24

TOTAL URINARY VOLUME
(cc.)

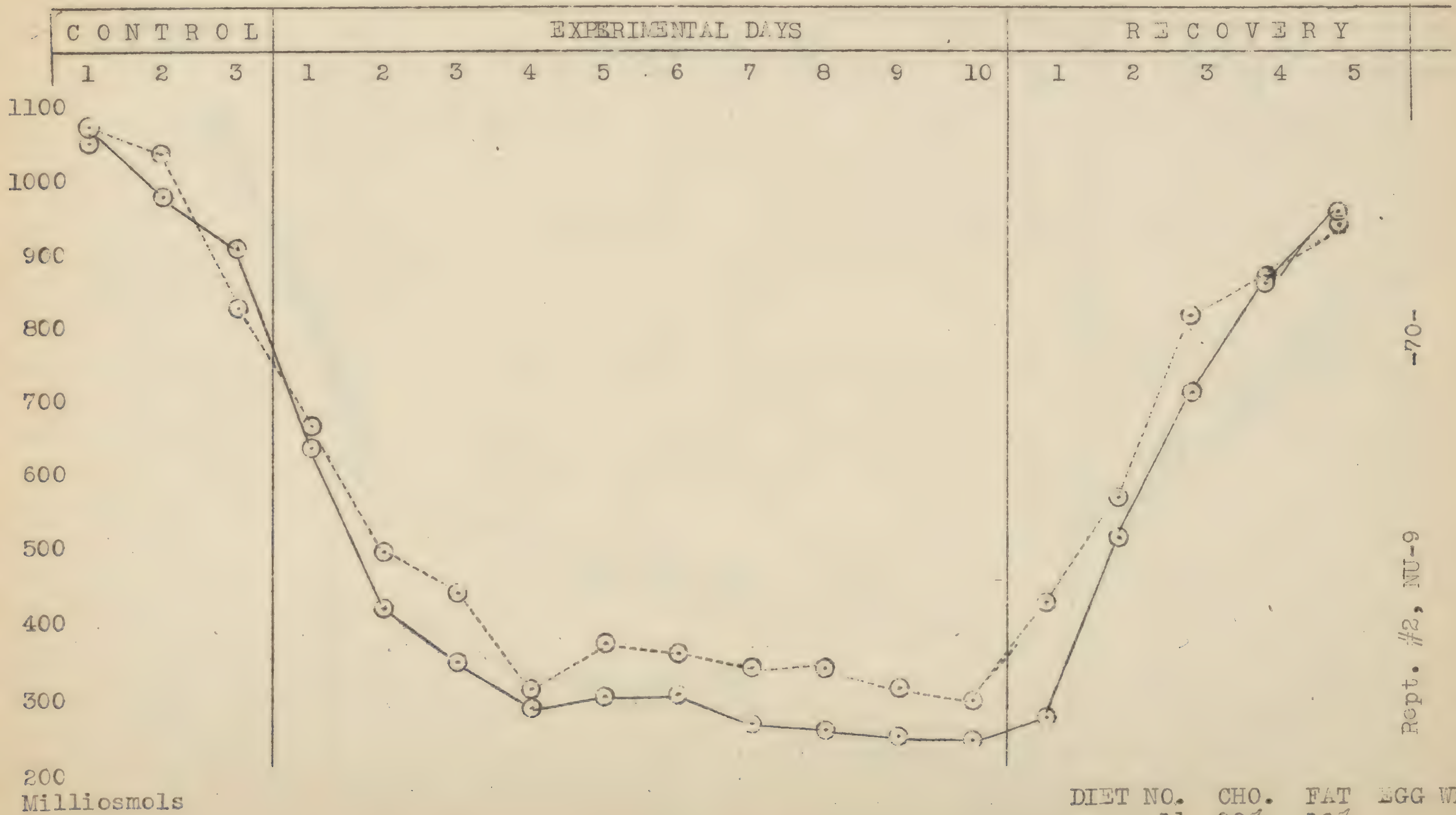


DIET NO.	CHO.	FAT	EGG WHITE
——— 11	90%	10%	
- - - 12	80%	10%	10%

(continued)
RESTRICTED

FIGURE 25

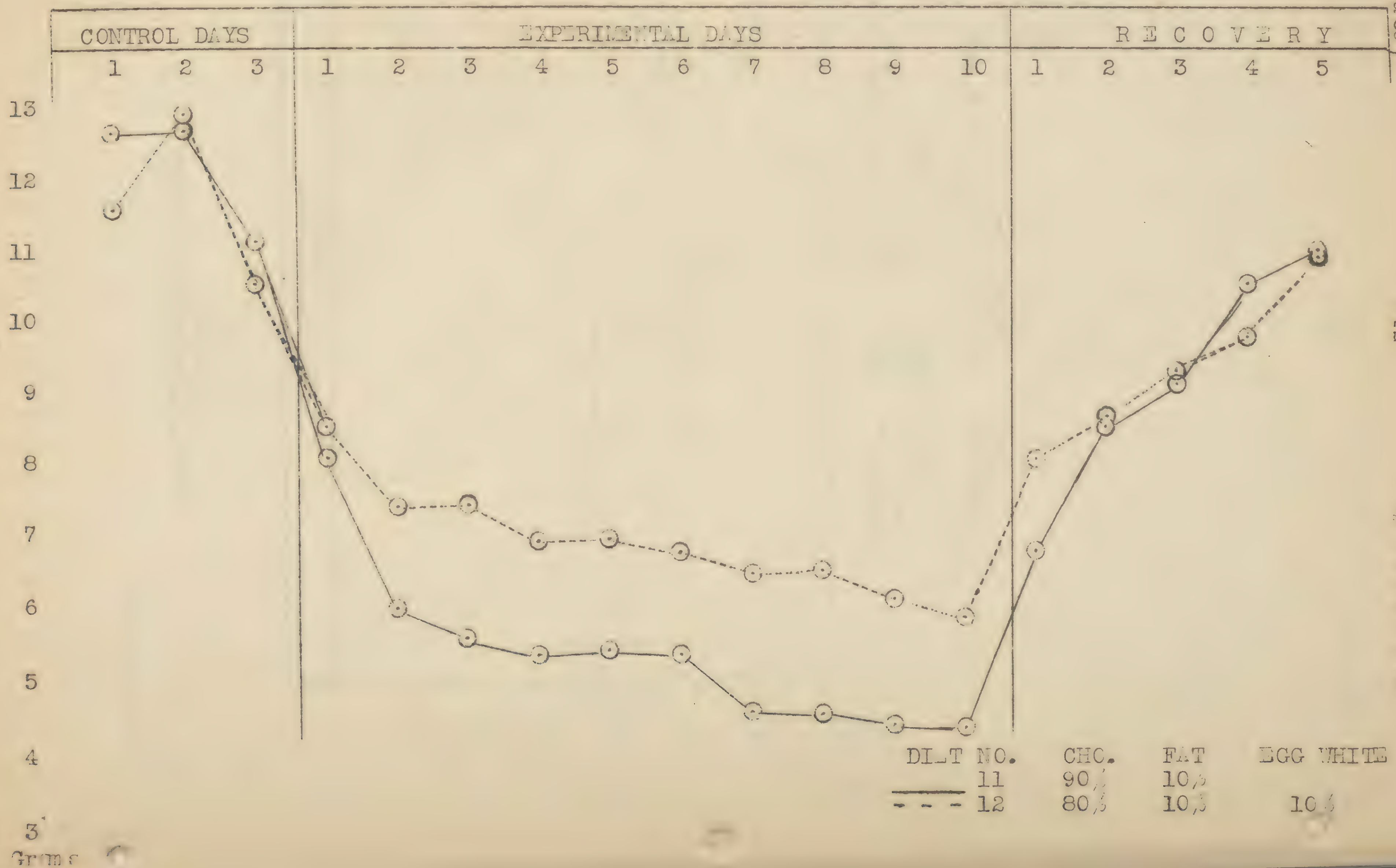
TOTAL SOLUTES IN URINE
(Milliosmols)



DIET NO.	CHO.	FAT	EGG WHITE
——— 11	90%	10%	
- - - 12	80%	10%	10%

FIGURE 26

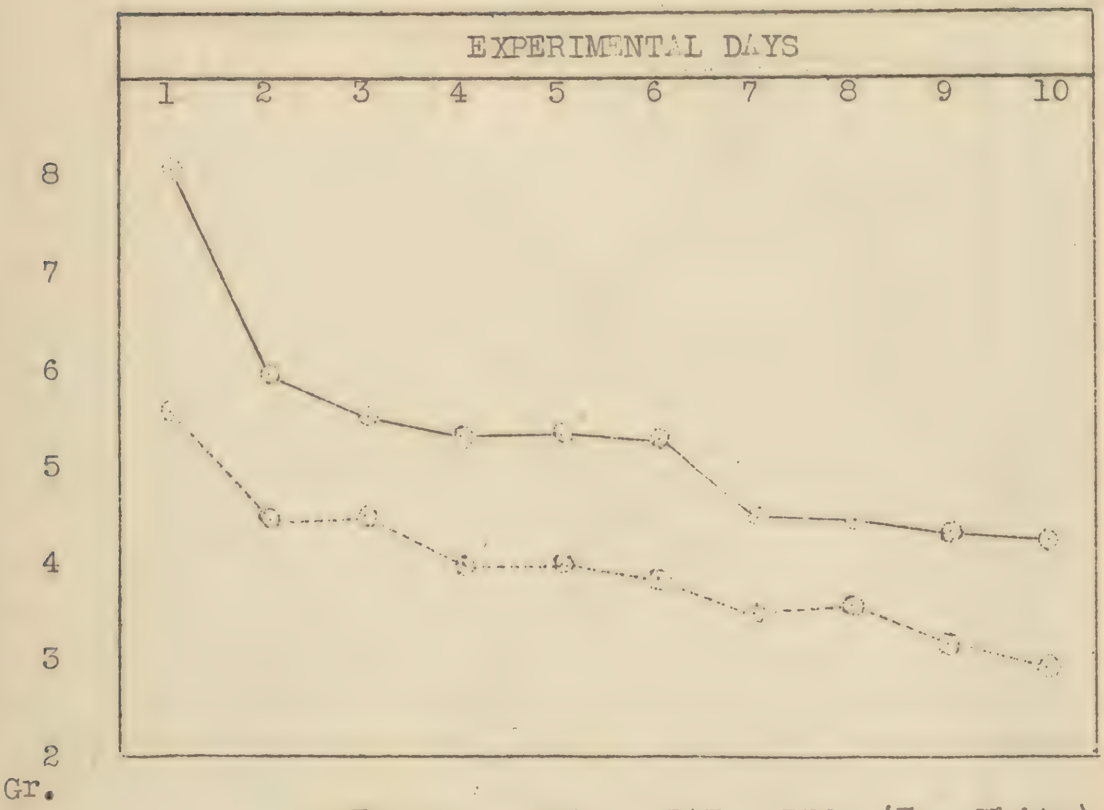
TOTAL NITROGEN IN URINE
(Grams)



(continued)
RESTRICTED

FIGURE 26A

NEGATIVE NITROGEN BALANCE
(Grams)

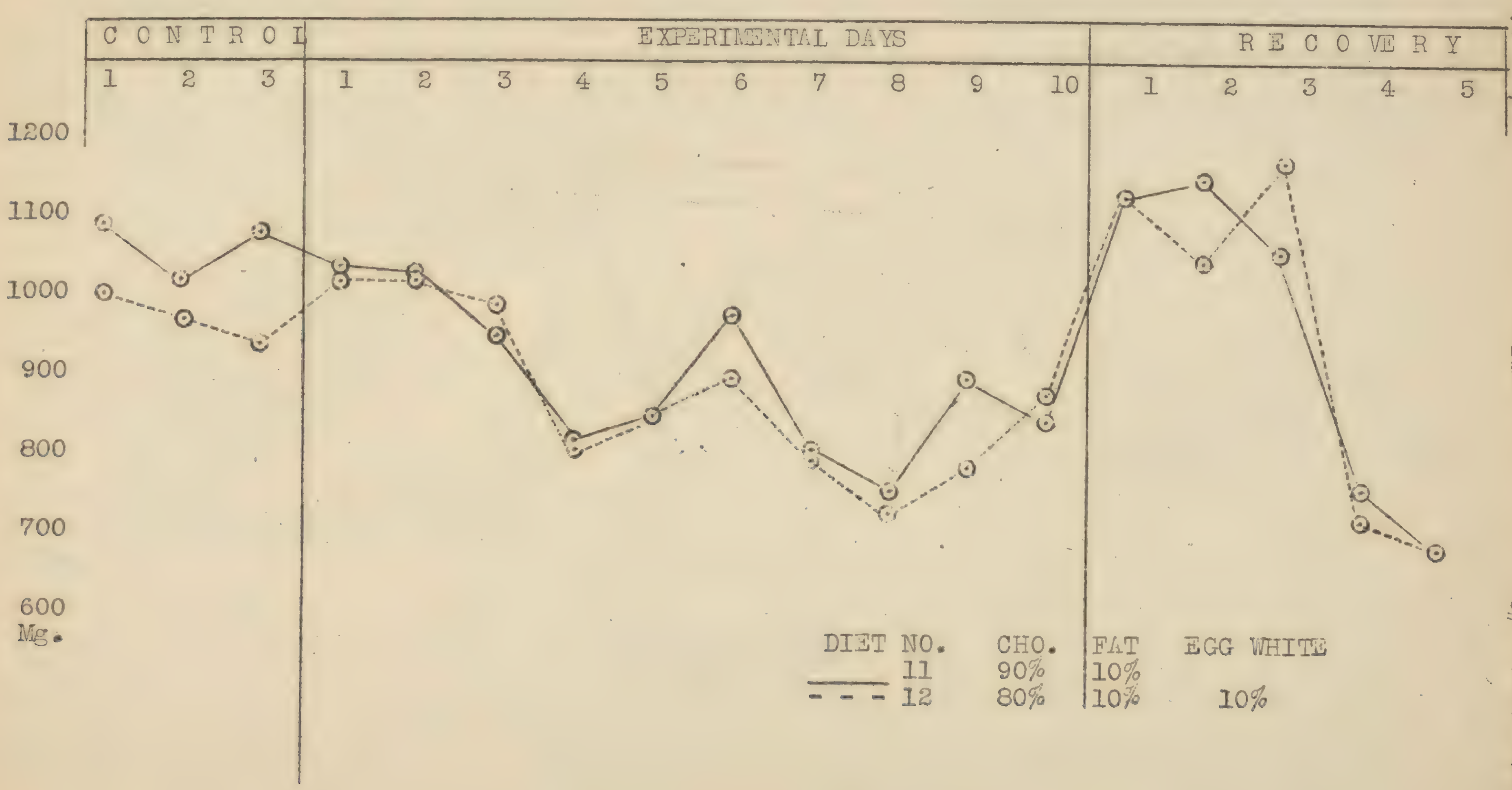


DIET NO.	CHO.	FAT	PRO. (Egg White)
—— 11	90%	10%	
----- 12	80%	10%	10%

DIET NO.	AVERAGE DAILY N_2 BALANCE
11	Minus 5.3
12	Minus 3.9

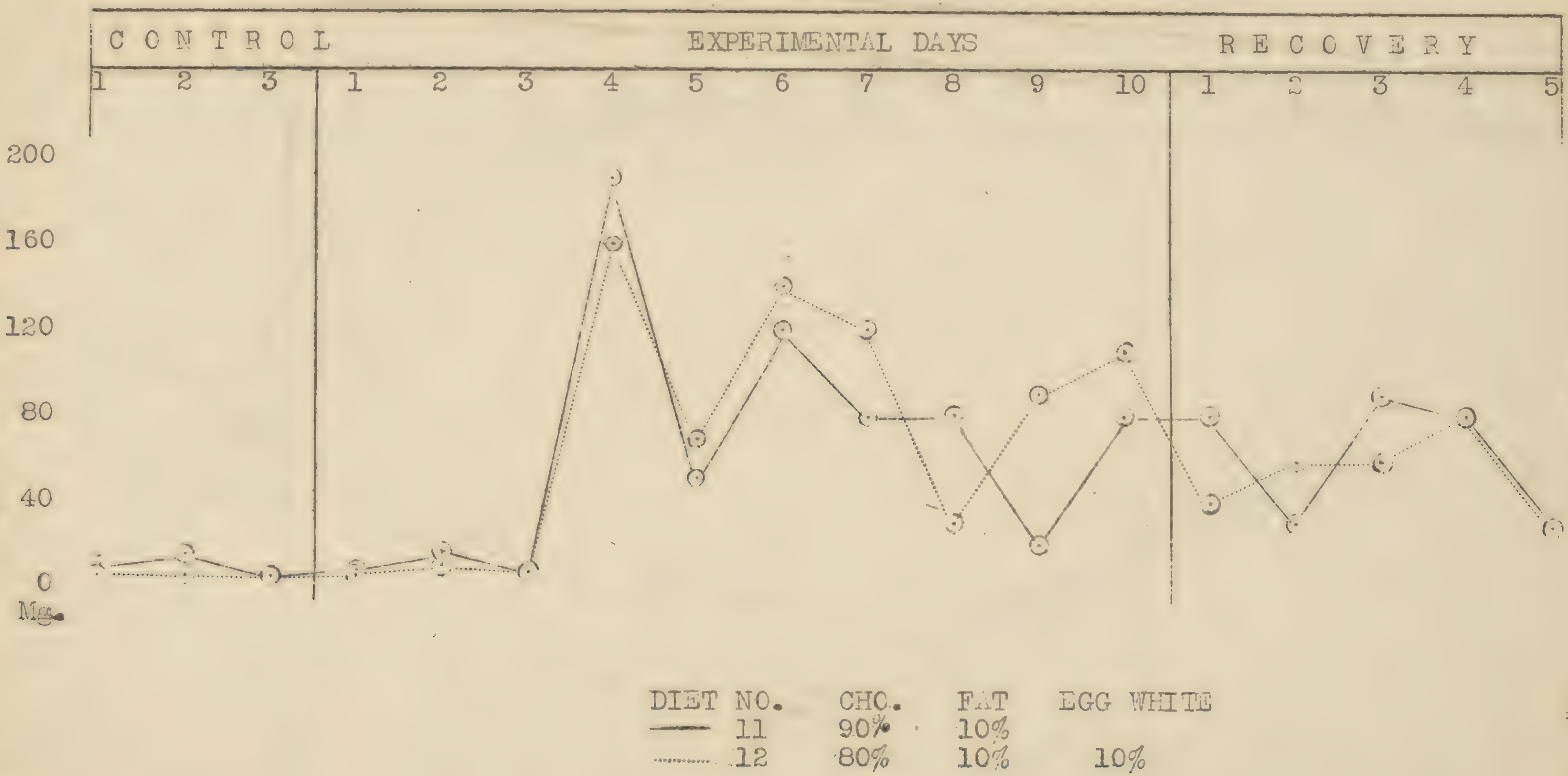
FIGURE 27

TOTAL CREATININE IN URINE
(Milligrams)



(continued)

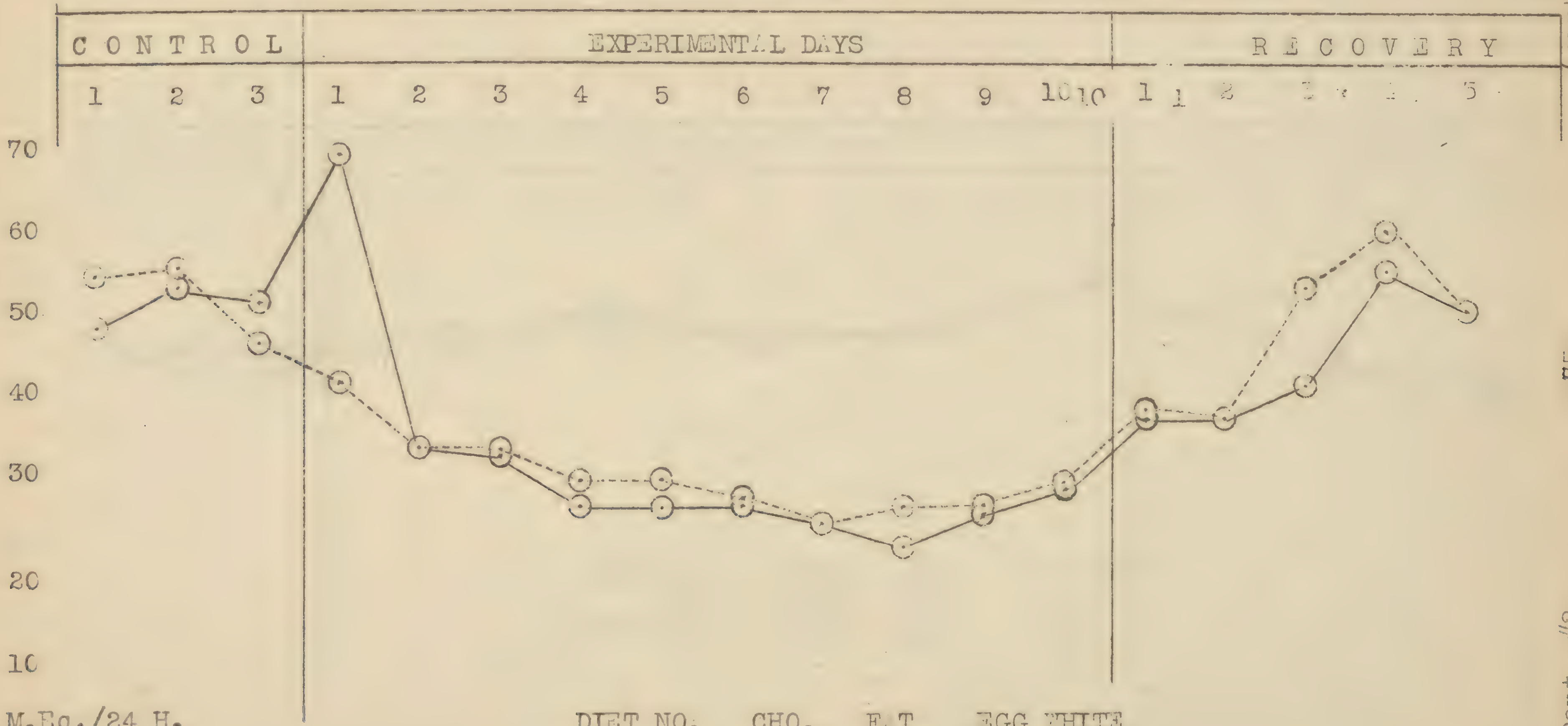
FIGURE 28 TOTAL CREATINE IN URINE
(Miligrams)



(continued)

FIGURE 29

TOTAL NH_3 NITROGEN IN URINE
(Milliequivalents Per 24 Hours)



DIET NO.	CHO.	FAT	EGG WHITE
——— 11	90%	10%	
- - - 12	80%	10%	10%

(continued)

FIGURE 30

BLOOD NON-PROTEIN NITROGEN
(Milligrams Per 100 cc.)

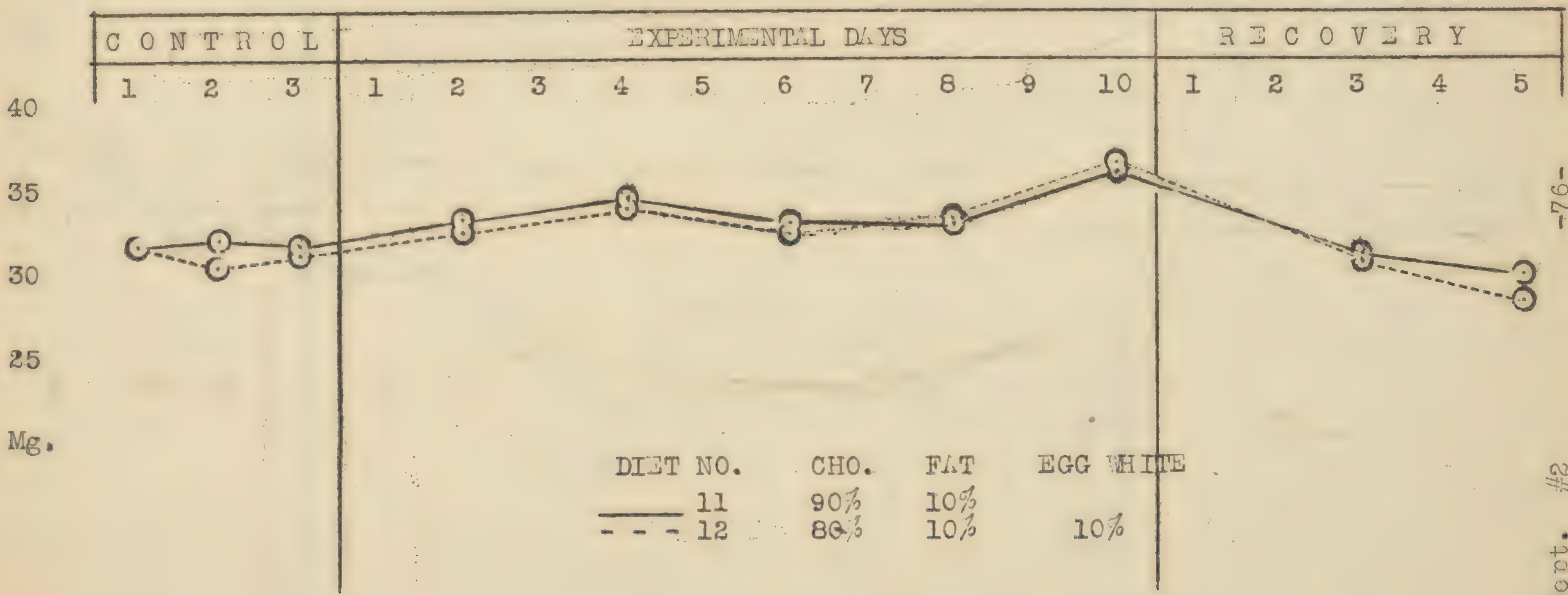
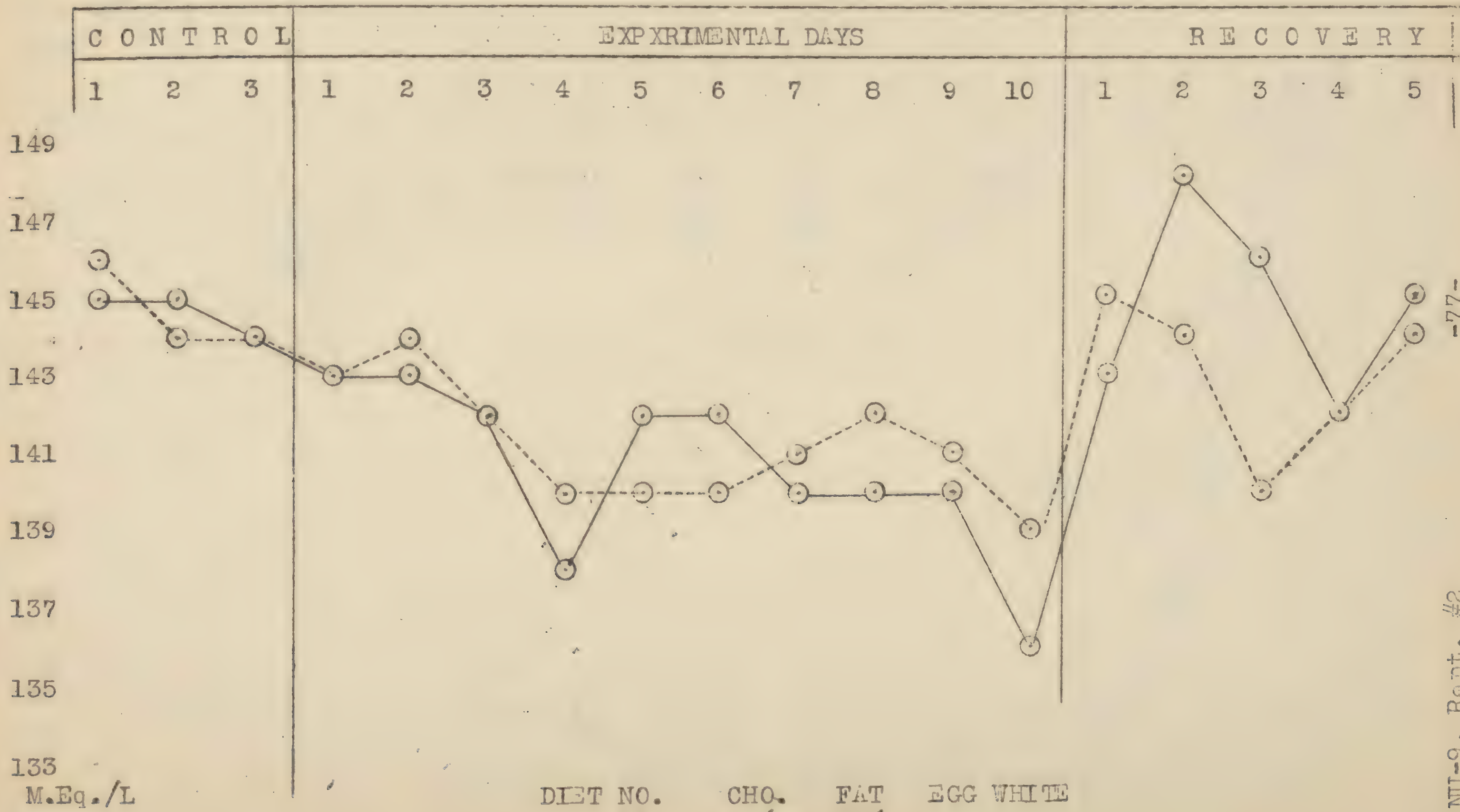


FIGURE 31

SERUM SODIUM
(Milliequivalents Per Liter)

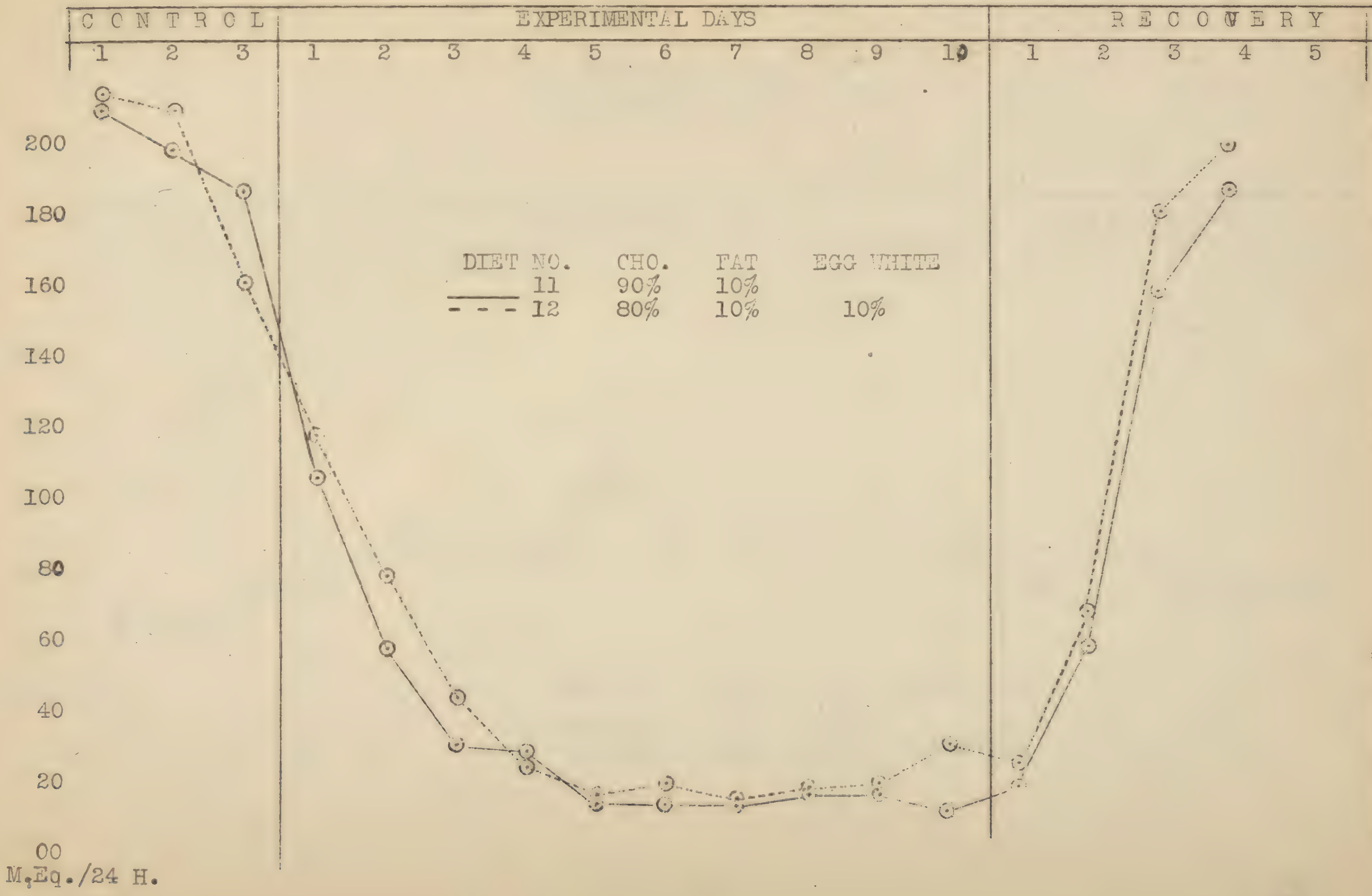


DIET NO.	CHO.	FAT	EGG WHITE
——— 11	90%	10%	
- - - 12	80%	10%	10%

(continued)

FIGURE 31A

TOTAL SODIUM IN URINE
(Milliequivalents Per 24 Hours)



(continued)

FIGURE 32

SERUM POTASSIUM
(Milliequivalents Per Liter)

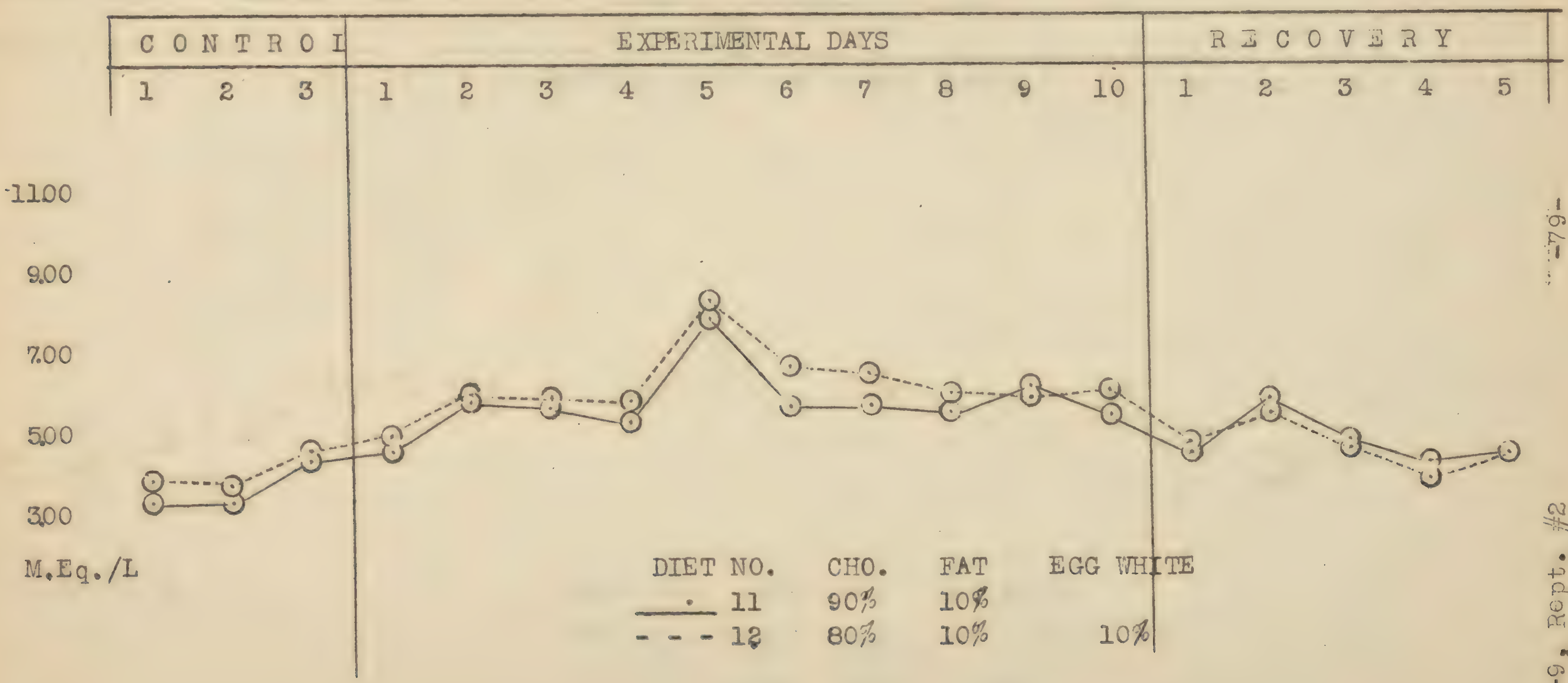
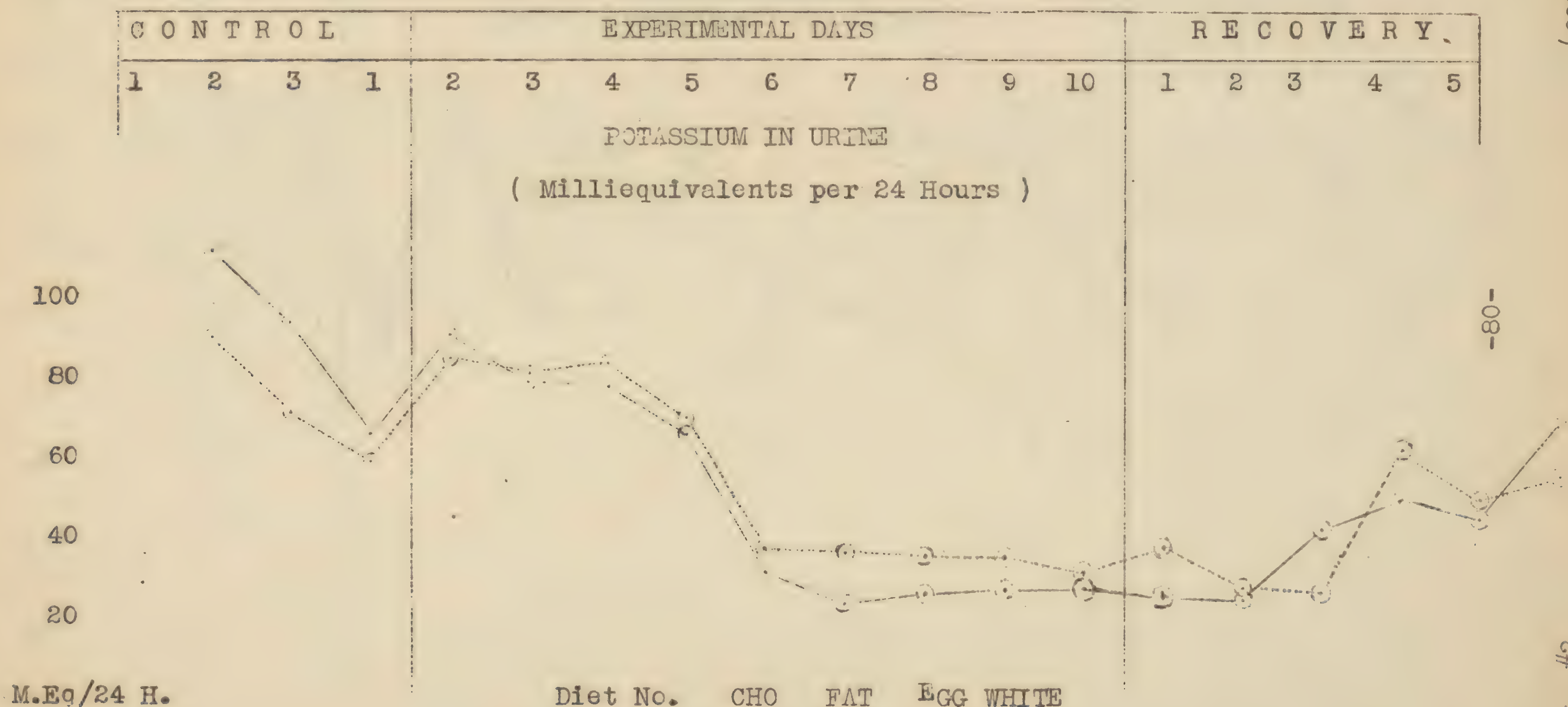


FIGURE 32A



Diet No.	CHO	FAT	EGG WHITE
--- 11	90%	10%	
···· 12	80%	10%	10%

(continued)

FIGURE 33

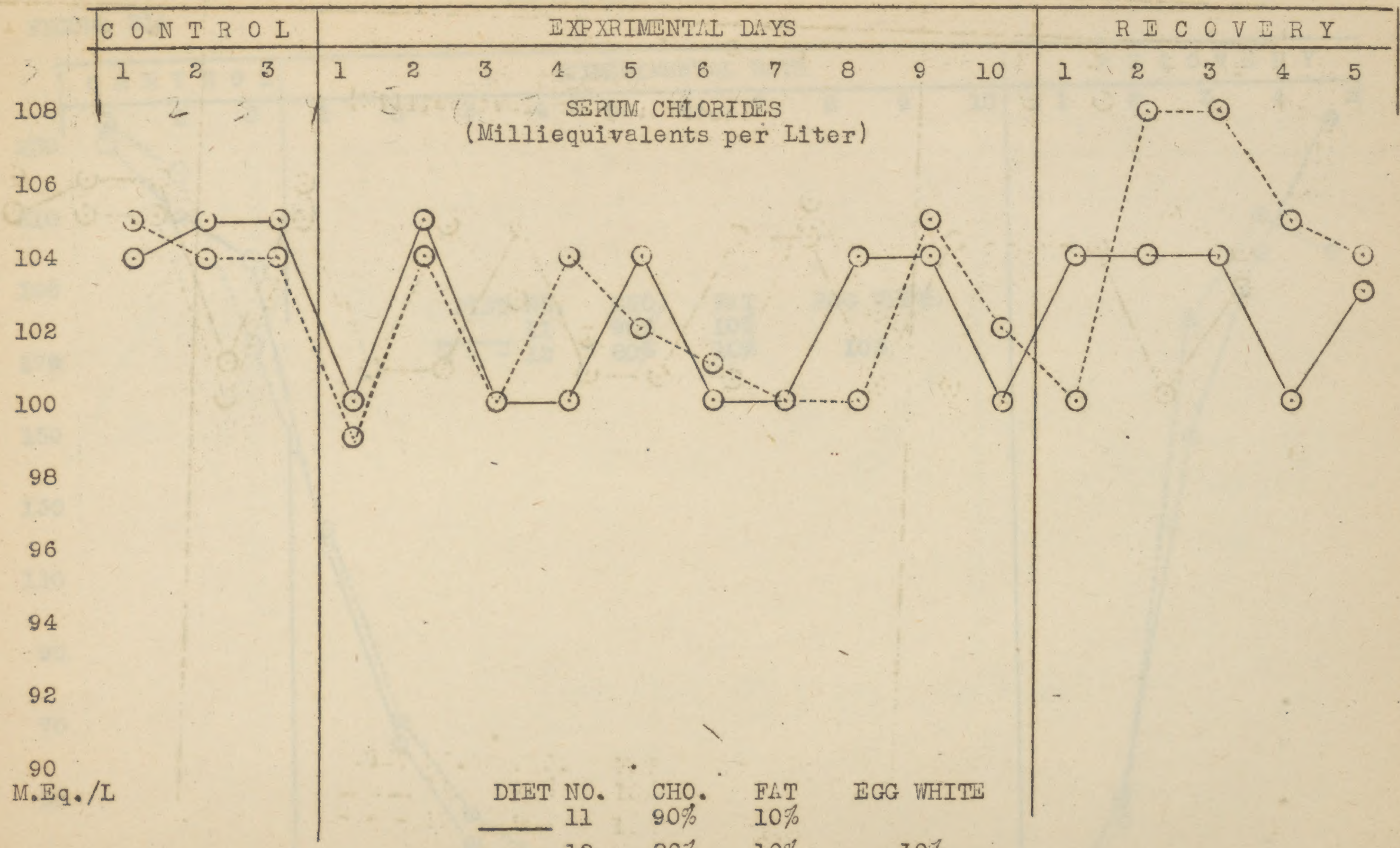

CONTROL
EXPXRIMENTAL DAYS
RECOVERY
1 2 3
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5
SERUM CHLORIDES
(Milliequivalents per Liter)
108
106
104
102
100
98
96
94
92
90
M.Eq./L
DIET NO. CHO. FAT EGG WHITE
11 90% 10%
12 80% 10% 10%

FIGURE 33A

TOTAL CHLORIDES IN URINE
(Milliequivalents Per 24 Hours)

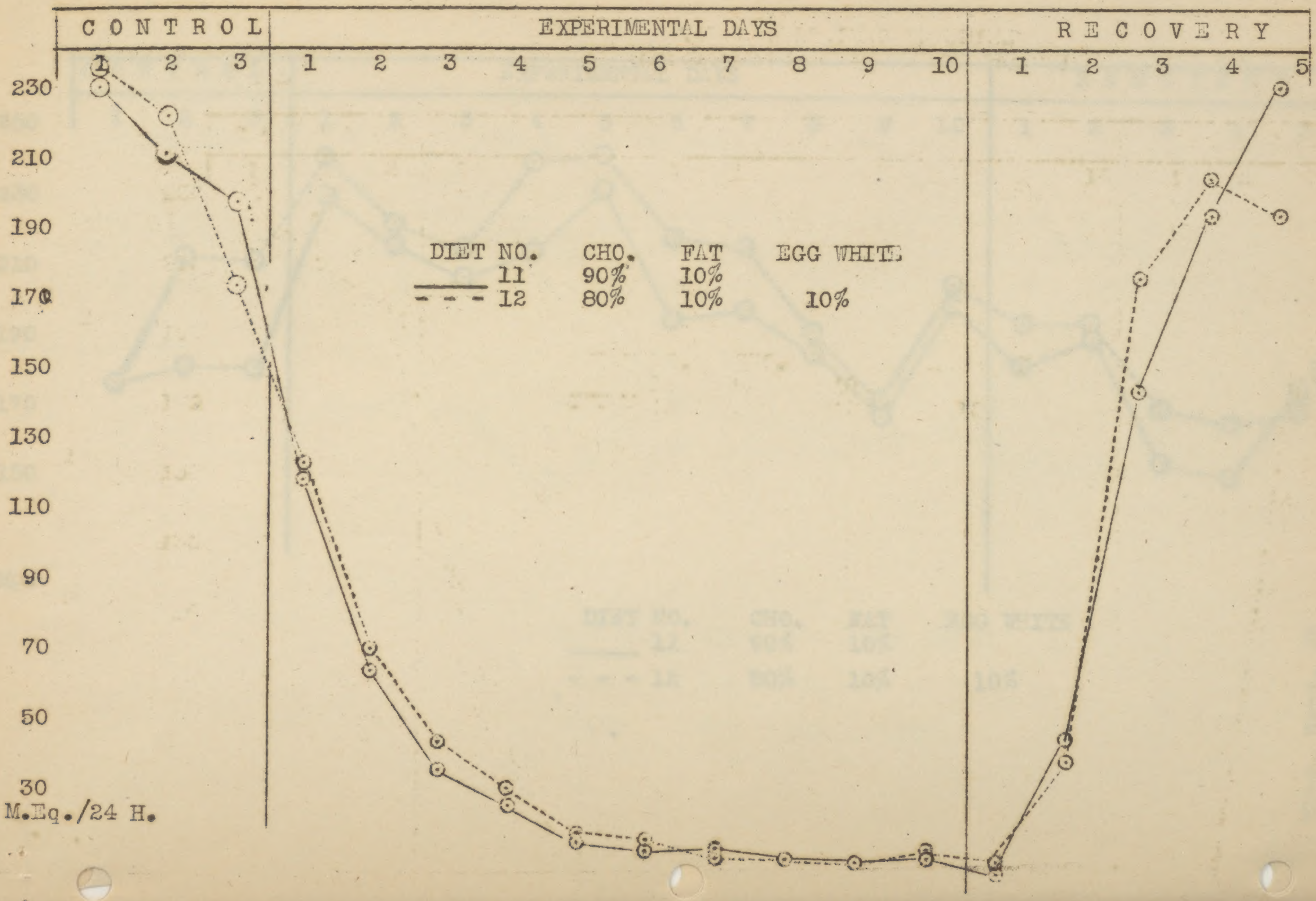
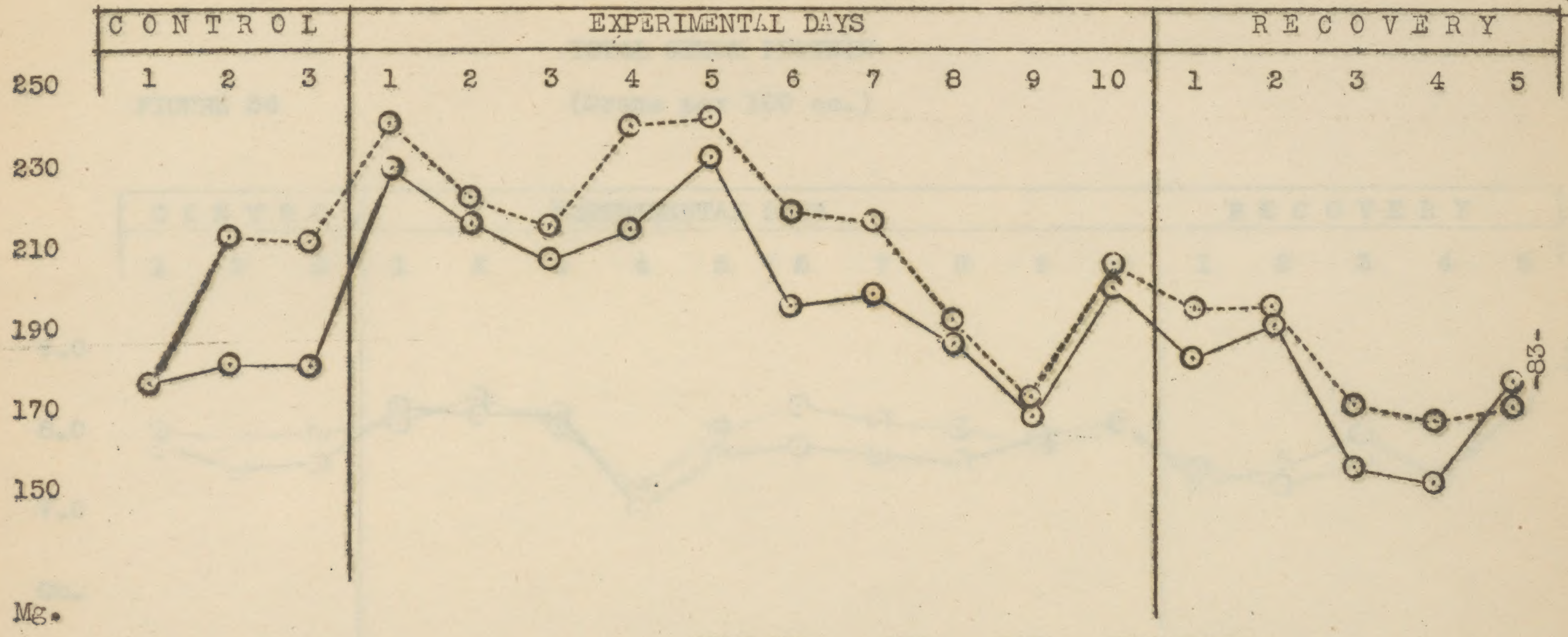


FIGURE 35

TOTAL SERUM CHOLESTEROL
(Milligram Per 100 cc.)

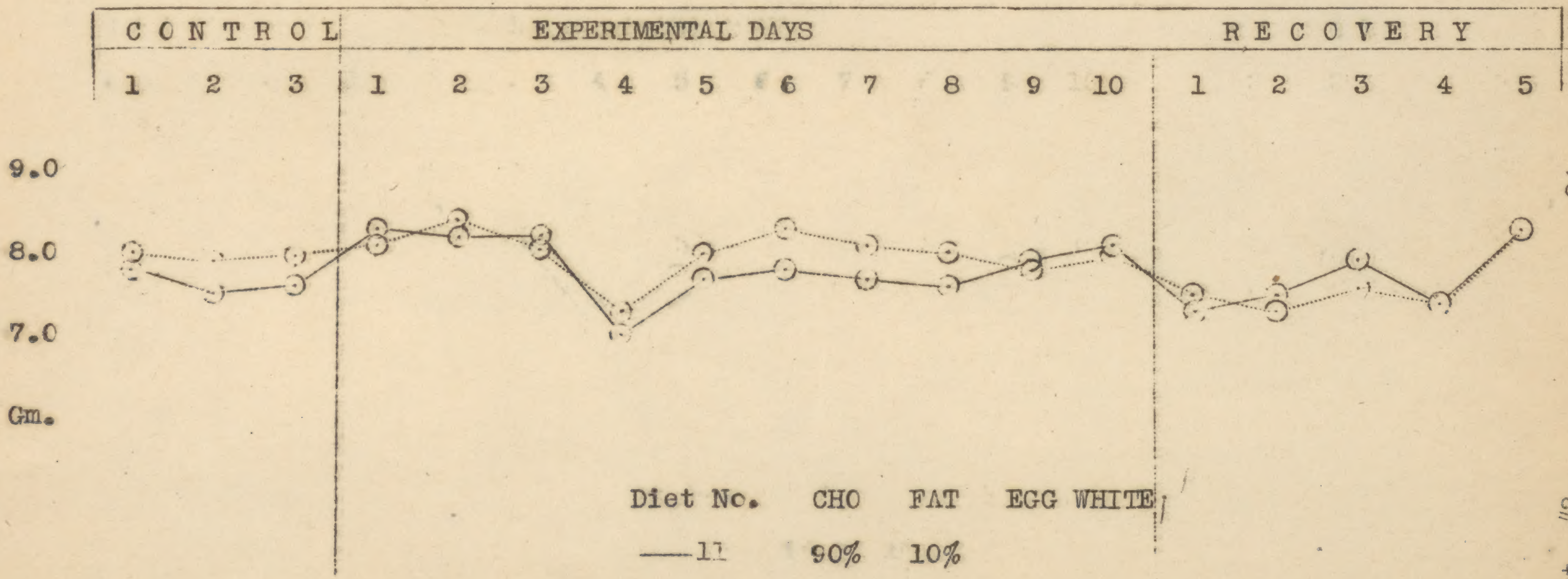


DIET NO.	CHO.	FAT	EGG WHITE
——— 11	90%	10%	
- - - 12	80%	10%	10%

FIGURE 36

TOTAL SERUM PROTEIN

(Grams per 100 cc.)



Diet No.	CHO	FAT	EGG WHITE
—— 11	90%	10%	
······ 12	80%	10%	10%